PROCEEDINGS OF THE UNEP/ESCAP/FAO WORKSHOP ON AGRICULTURAL AND AGRO-INDUSTRIAL RESIDUE UTILIZATION IN THE ASIAN AND PACIFIC REGION

Pattaya, Thailand, 10-14 December 1979

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Proceedings of the UNEP/ESCAP/FAO Workshop on Agricultural and Agro-industrial Residue Utilization in the Asian and Pacific Region

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PREFACE

In mid-1979 a project for the Asian and the Pacific Region was initiated by ESCAP, UNEP, and FAO as a continuation of effects to identify opportunities for agricultural and agro-industrial residue utilization and to stimulate development of appropriate technologies and systems for residue utilization. Recommendations made at an earlier global seminar on "Residue Utilization-Management of Agricultural and Agro-industrial Waste" provided the broad framework for the current project. Through these recommendations plans were made to focus activities at the regional level on crops which had associated with them known residue problems. In the context of Asia and the Pacific these crops were identified as paddy, sugarcane, maize, cassava, coconut, oil palm and rubber. It was further decided to match the residues from each crop to specific end-uses which included, energy, human food, animal feeds, fertilizers, construction materials, handicrafts, chemicals and water (for such purposes as human and industrial consumption and irrigation).

An assessment of the residues from the seven crops and their potential end-uses were to be presented from the point of view of their environmental impact and from the technologies available and needed for their control. It was also thought that consideration should be given to the socio-economic and institutional aspects for successful utilization of agricultural and agro-industrial residues.

Given this basic framework a mission was launched in August 1979 to collect information on agricultural and agro-industrial residue utilization in five countries of Asia: Malaysia, Pakistan, Philippines, the Republic of Korea and Thailand. The mission team was composed of Messrs. J.C. Williams (ESCAP and team leader), Dhira Pantumvanit (UNEP), N.C. Thanh (consultant from the Asian Institute of Technology) and Brian Webb (consultant from the University of Malaya).

/In addition

In addition to the information collected by the mission team several project consultants provided further details on specific aspects of residue utilization. This information included a global overview of residue utilization (Mr. R.C. Loehr, Director, Environmental Studies Programme, Cornell University, U.S.A.), a discussion of the commercialization aspects of residue products (Ms. Malee Sundhagul, Director of the Asian Centre for Population and Community Development and Director of the Bangkok Microbiological Resource Centre, Thailand) and the experience of India in agricultural and agro-industrial residue utilization (Mr. O.P. Vimal, Indian Agricultural Research Institute, India).

The results of the mission and consultant investigations were presented as a series of papers on agricultural and agro-industrial residue utilization at an intergovernmental workshop held in Pattaya, Thailand on 10 to 14 December 1979. Representatives from twelve countries in the Asia and Pacific region attended the workshop, prepared and adapted a report which concentrated on the status and needs for continued development of residue utilization and proposed recommendations for follow-up action for this purpose.

The papers published in this monograph are those presented to the participants of the Workshop on Agricultural and Agro-industrial Residue Utilization for Asia and the Pacific region. The report of the workshop and a list of workshop's participants are also included.

The workshop papers are ordered in a manner to best aquaint the reader with the field and issues of agricultural and agro-industrial residue utilization in the Asia and Pacific region. First an overview of residue utilization is presented after which the pollution control and management aspects of residues are detailed with special reference to waste-water discharges. The technical and socio-economic aspects of agricultural and agro-industrial residue utilization is presented in the next two papers. These papers are followed by a study on the current and potential institutional arrangements for use of such residues. Finally two papers are presented on special aspects of residue utilization: The commercialization of research results and a detailed country report on residue utilization in India.

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It is believed by the sponsoring organizations that the papers presented in this publications are to date the most comprehensive and complete information about agricultural and agro-industrial residue utilization in the Asia and Pacific region. They are presented to stimulate further understanding and development of this most important environmental field.

December 1981

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ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC,
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10-14 December 1979
Pattaya, Thailand

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REPORT OF ESCAP/UNEP/FAO WORKSHOP ON AGRICULTURAL
AND AGRO-INDUSTRIAL RESIDUE UTILIZATION IN THE ESCAP REGION

REPORT OF ESCAP/UNEP/FAO WORKSHOP

ON

AGRICULTURAL AND AGRO-INDUSTRIAL RESIDUE UTILIZATION

IN THE ESCAP REGION

ESCAP Document AD/WAAIRU/8, 28 January 1980

A. ORGANIZATION OF THE SESSION

1. The ESCAP/UNEP/FAO sponsored Workshop on Agricultural and Agro-industrial Residue Utilization was held at Pattaya, Thailand, from 10 to 14 December 1979. Consultants, the secretariat and the representative from the Biological Waste Management Laboratory, United States Department of Agriculture read their papers on 10-11 December 1979. Two working Groups were formed on 12 December 1979 to discuss (a) the technical and end use aspects of agricultural and agro-industrial residue utilization and (b) the institutional and socio-economic aspects of such residue utilization. The discussions by the working groups concluded on 13 December 1979. The Workshop report was adopted on 14 December 1979.

Attendance and opening statements

2. The Workshop was attended by twelve representatives of the following Governments: Bangladesh, Indonesia, Lao People's Democratic Republic, Malaysia, Maldives, Pakistan, Papua New Guinea, the Philippines, the Republic of Korea, Sri Lanka, Thailand and Viet Nam. The following inter-governmental and governmental organizations were represented : ASEAN Sub-committee on Food Waste, Biological Waste Management and Organic Resources Laboratory, United States Department of Agriculture, and the Philippines Coconut Authority. Consultants and resource personnel were provided by the Asian Institute of Technology, Bangkok, Thailand, the Chemical Engineering Department, Faculty of Engineering, University of Malaya, Kuala Lumpur, Malaysia, the Division

/of

of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute, New Delhi, India, the Asian Centre for Population and Community Development and the Bangkok Microbiological Resource Centre, Thailand, and the Environmental Studies Programme, Cornell University, New York, United States of America.

3. In his message to the Workshop the Executive Secretary of ESCAP stated that the Workshop provided a good example of interagency and regional co-operation as it involved the United Nations Environment Programme (UNEP), the Food and Agriculture Organization of the United Nations (FAO), the Government of the Netherlands and the Government of Thailand. He pointed out that the Workshop evolved as a direct result of the 1977 Seminar in Rome on the Management of Agricultural and Agro-industrial Residues sponsored jointly by UNEP and FAO, which inter alia recommended that effort should be made at the regional level to expand the knowledge of the uses of the most common agricultural and agro-industrial residues found therein. The Workshop was the first regional attempt to satisfy that recommendation. He requested the Workshop to consider the future of the residue utilization approach and to recommend, in realistic and concrete terms, a course of action whereby national programmes would develop and international assistance be focused through follow-up activities.

4. The Deputy Regional Representative for Asia and the Pacific of UNEP welcomed the participants to the Workshop. He emphasized the immense potential in residue utilization in the region. The utilization of residue in some instances would in itself serve in abating environmental pollution, particularly those which were related to agro-industry. In this connexion, he referred to the Consultative Meeting on Renewable and Reuseable Resources in terms of agricultural and agro-industrial residues organized in Bangkok by UNEP in March 1979 with participants from eight countries in the region, both developed and developing. That meeting fully endorsed the idea of establishing a regional network of research institutes as a first step towards the setting up of a regional programme on residue utilization.

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5. In his statement, the Senior Programme Officer, Industry and Environment Office, UNEP, Paris, mentioned that the topic of residue utilization was a key component of UNEP's strategies and activities and resource management was synonymous with environmental management. There was a need to evolve from a consuming society to one that conserves. Non-renewable and even some renewable resources were getting scarce and becoming unavailable. Rational and pragmatic steps on residue utilization implemented at that time would enhance and increase the resource base. Furthermore, such a strategy could pre-empt emotional and irrational actions under crises conditions, when resources become even more scarce. He briefly reviewed the activities of UNEP's Industry and Environment Office. He noted that all the industrial sectoral reviews endeavoured to identify, promote and disseminate low and non-waste technologies which encompassed residues' reclycling and utilization. He observed that the objective of the Workshop was to promote and catalyse increasing activities in agricultural and agro-industrial residue utilization in countries of the ESCAP region, especially on seven crops common to that region: rice, sugarcane, maize, coconut, cassava, oil palm and rubber, in order to disseminate information resulting from the Workshop, to provide elements for developing guidelines on agricultural and agro-industrial residue utilization; and to formulate and implement strategies and activities.

Election of officers and adoption of agenda

6. The Workshop elected Mr. W. Weeraratne (Sri Lanka) as Chairman and Ms. Lorna C. Dipasupil (Philippines) as Vice Chairman. Mr. Haleem Ul Hasnain (Pakistan) was elected Rapporteur.

7. The following agenda was adopted.

1. Opening of the Workshop
2. Election of Officers
3. Adoption of the agenda
4. Presentation of reports on the utilization of agricultural and agro-industrial residues

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/(a)

(a) An overview of residue utilization

(b) Environmental pollution aspects of agricultural and agro-industrial residues

(c) Technological aspects of agricultural and agro-industrial residue utilization

(d) Socio-economic aspects of agricultural and agro-industrial residue utilization

(e) Institutional aspects of agricultural and agro-industrial residue utilization

(f) Review of FAO activities on agricultural and agro-industrial residue utilization.

(g) Agricultural and agro-industrial residue utilization : the experience of India

(h) Commercialization of research results on utilization of agricultural and agro-industrial residues : case study from Thailand

5. Discussion of future activities in the field of agricultural and agro-industrial residue utilization.

6. Field trip to a tapioca starch agro-industry

7. Other matters

8. Adoption of the report.

B. DISCUSSIONS AND RECOMMENDATIONS

1. Introduction

8. Residues from agriculture and agro-industries were defined as the non-product outputs from the growing and processing of raw agricultural products such as fruits, vegetables, meat, poultry, fish, milk, grain, and trees. While such outputs (i.e. residues) might contain material that could be of benefit to people, their economic values were

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usually less than the apparent cost of collection, transportation and processing for beneficial use. It was recognized that whenever residues could be utilized for human benefit their subsequent gain in economic value changes their output status from that of non-product to product. For certain residues, such a change had already occurred, bringing with it new and useful products.

9. Within the region there had been a marked increase in the quantity of residues generated as a result of increases and changes in agricultural production and in processing of raw agricultural produce into consumable products. The recycling and utilization of agricultural residues were of serious concern in view of: (a) the environmental hazards resulting from their non or under-utilization and (b) the shortage of resources to meet the growing needs of the increasing population, rapid industrialization and expanding urbanization in the region.

10. Efficient utilization of agricultural residues was limited by socio-economic and institutional factors as well as by knowledge about the quantity and characteristics of the available residues and the appropriate technology to utilize the residues. To accomplish effective residue utilization, all such factors had to be considered in an integrated approach.

11. A vast amount of agricultural and agro-industrial residues were generated in the region. To provide a manageable focus in the workshop, the following seven crops were considered: rice, sugarcane, maize, cassava, coconut, rubber and oil palm. It was hoped that such a focus would stimulate interest in residues from other agricultural activities that might be generated in specific countries.

12. Several end-uses were emphasized: energy, human food; animal feeds, fertilizers, construction materials, paper and paper board, handicrafts, chemicals, and water (for such purposes as human and industrial consumption and irrigation). Each crop was considered in terms of its applicability to those end uses.

/13.

13. It was emphasized that numerous opportunities existed for utilization of residues from specific crop production and crop processing operations. In addition, it was noted that there were opportunities to integrate the utilization of residues from several production and processing operations. For example, food processing residues might be used to feed animals, the manure from which could be used for fish production. Another example could be the use of sugarcane bagasse to provide the energy for production of ethanol from cassava. Integrated utilization of residues should be considered in as broad a manner as possible.

2. Current status of agricultural and agro-industrial residue utilization

14. Table 1 shows the current and potential end-uses of residues from the growing and processing of rice, sugarcane, maize, cassava, coconut, rubber, and oil palm in the ESCAP region. Four time-base classifications were selected to reflect the status of utilization, technology and product obtained. Six different end-uses: renewable energy source; food and animal feeds; fertilizers; construction materials, paper and handicrafts; chemicals; and water were designated to categorize the various residues.

3. Observed needs

Institutional

15. The institutional needs, with specific reference to agricultural and agro-industrial residues, were noted to be :

(a) An agency to co-ordinate residue utilization programmes in each country;

(b) Information on residue availability in the light of their local uses, bulky and perishable nature and transportation difficulties;

(c) Awareness of environmental hazards resulting from indifferent residue utilization or non-utilization;

/(d)

(d) Appropriate training facilities and information media on residue utilization;

(e) Effective linkages between agro-industry and research and development institutions;

(f) Market surveys on the potential demand for end-products vis-a-vis alternative products;

(g) Exchange of personnel and information among the regional countries;

(h) Model course curriculum on agricultural residue management.

Technical

16. It was the consensus that all countries of the ESCAP region should proceed as soon as possible to compile an up-to-date and comprehensive survey of the kinds, amounts, availability and technological aspects of agricultural and agro-industrial residues that were being generated within each country. Such information was urgently needed to assess the current status of residue production and use, and to develop realistic plans for better utilization. It was also an absolutely essential pre-requisite if current institutional, technological, and socio-economic constraints are to be overcome.

17. It was noted that there was a need for countries of the ESCAP region to follow a standard format in compiling their surveys and that such surveys be exchanged among the countries of the region. Such comprehensive surveys could contain the following information :

(a) Kinds and amounts of residues generated;

(b) Current availability and usage;

(c) Chemical composition and characteristics of the residues related to specific end-uses;

(d) Potential alternative uses of the residues;

/(e)

(e) Problems and constraints affecting usage;

(f) Available technology and specific operating parameters;

(g) Potential uses and needed technology;

(h) Research and development needs;

(i) Comprehensive mass balance flow sheets for the processing of each crop;

(j) Comprehensive crop production data;

(k) An assessment of the economic and social benefits of environmental protection.

18. There was a need for appropriate and integrated technology commensurate with local conditions and chemical composition of residues.

19. There was also a need to assess the capabilities of transportation facilities in view of the possible increased processing and utilization of residues.

4. Recommendations

20. The Workshop made the following recommendations :

1. A specific unit should be set up at the regional level on agricultural residue management sponsored by ESCAP/UNEP/FAO and other international agencies with the following objectives :

(a) To establish a documentation centre and data bank for collection, compilation and retrieval of technical and non-technical information on the availability and utilization of agricultural residues;

(b) To promote exchange of personnel and information among the regional countries.

2. A lead agency should be designated in each country to coordinate residue utilization programmes at the national level with the following objectives :

/(a)

(a) To serve as an information system and data bank for collection, compilation and dissemination of information relating to management of agricultural residues in the form of reports, data sheets and bulletins;

(b) To act as a focal centre for contact with its counterparts in other countries and international agencies;

(c) To create awareness through symposia, training programmes and appropriate publications.

3. There should be a compilation, in a standard format, of an up-to-date and comprehensive survey of the kinds, amounts, availability and technical aspects of agricultural and agro-industrial residues that are now being generated within each country.

4. Research and development programmes should be initiated in the following priority areas :

(a) Renewable energy sources :

(i) Re-evaluation of the potential use of rice husk for energy (solid fuel);

(ii) More research and development on fermentation of molasses to ethanol with particular reference to improve the economics of production (i.e. to lower the production cost);

(iii) Strain improvement of cellulose-digesting fungi, and increased digestibility of cellulosic material through improved/innovative technology;

(iv) Improvement of bio-gas technology with regard to (a) materials and design problems leading to plant failure from corrosion, (b) design and operational problems resulting in plant failure under low temperature conditions, (c) combinations of residue feedstocks to enhance operational flexibility of bio-gas plants, and (d) the investigation of the persistence of human pathogens in bio-gas sludge that is applied to land.

/(b)

(b) Food and animal feeds :

(i) Development of special (integrated) recycling systems --- for example, processed residues (first degree) might be fed to poultry, and their waste which becomes a second degree residue might then be used for fish, livestock and crop production;

(ii) Selected feeding trials to determine the animal's capability for utilizing various types of residues for feed. For example, there was some indication that buffalo can better utilize cereal straws for feed than do cattle. Information was needed on appropriate technology and treatment of ligno-cellulosic wastes to enhance their digestibility for both ruminant and non-ruminant animals.

(c) Fertilizers :

(i) Additional research on the rate and frequency of application of rubber effluent for irrigation and growth of oil palm to prevent undesirable accumulation of nitrates in soil and minimize groundwater contamination from leaching;

(ii) Research and demonstration projects to determine methods and techniques for accelerating the rate of composting ligno-cellulosic residues;

(iii) Renovation of certain high BOD (Biological Oxygen Demand) waste waters by simple and low-cost land treatment methods. The plant nutrient content of certain waste waters would provide considerable fertilizer value for the growth of crops. Demonstration projects are needed in this regard.

(d) Construction materials, paper and handicrafts: New uses for such residues as rubber wood and fibrous waste. For example, chemical treatment might enhance their use, longevity, fire resistance, and accoustical properties.

(e) Chemicals: Increase utilization of ligno-cellulosic residues (i.e., cereal straws) for use as chemical stock in the synthesis of other chemicals, plastics, and textiles;

/(f)

(f) Water: Investigate coupling agricultural processing industries based on their usage and water quality requirements through feasibility studies. That would ensure the effective and efficient reuse of water with minimum impact on the environment.

C. PRIORITY FOLLOW-UP ACTION

21. The Workshop noted that there was a need to identify a limited number of activities drawn from the recommendations for urgent follow-up action. Three activities were, therefore, selected for priority follow-up action to be undertaken immediately on agricultural and agro-industrial residue utilization;:

(a) Each Government should designate a lead agency to co-ordinate residue utilization programme at the national level;

(b) Each country should carry out a survey using a standard format on the kinds, amounts, availability and technical aspects of agricultural residues as stated in paragraphs 16 and 17;

(c) ESCAP in collaboration with UNEP, FAO and other relevant international agencies should organize an interagency meeting by June 1980 in order to :

(i) Establish a mechanism to promote and co-ordinate residue utilization programmes in the region, within the framework of ESCAP, UNEP, FAO and other relevant international organizations;

(ii) Promote the dissemination and exchange of information through national and regional newsletters. Initially this could be started as part of existing newsletters published by international organization and national agencies; ultimately a regional newsletter dealing with residue utilization should be developed;

(iii) Develop guidelines on residue management and utilization (including environmental management) for planners and decision-makers.

/Also,

Also, prepare technical manuals on major end-uses, taking into consideration and incorporating where appropriate, existing work undertaken by other international organizations;

(iv) Establish a regional forum for periodic exchange of information, experience and viewpoints targeted at the policy, managerial, and technical levels. This would be in the form of, for example, meetings, exchange programmes, and fellowship schemes;

(v) Investigate and evaluate potential residue utilization and associated environmental management projects through technical and socio-economic pre-investment studies which would lead to project implementation.

/Table 1

Table 1. End-use potential of seven selected crops (rice, maize, cassava, sugarcane, coconut, oil palm and rubber)

Note: The time base potential is designated as follows :

Present use	P	
Immediate potential	I	(1 to 2 years)
Mid-term potential	M	(3 to 5 years)
Future development	F	(5 to 10 years)

End use	Residue	Product	Time-base Potential
1. Renewable energy sources	Mollases	Ethanol	P
	Cassava	Ethanol	P
	Sugarcane	Ethanol	P
	Bagasse	Solid fuel	P
	Oil palm fibre	Solid fuel	P
	Coconut shell	Charcoal	P
	Coconut leaf	Solid fuel	P
	Cassava stems	Solid fuel	P
	Rice husk	Solid fuel	P
	Rubber wood	Solid fuel	P
	Coconut stem	Charcoal	I
	Coconut husk	Charcoal	I
	Ligno-cellulosic wastes	(Char-oil (gas	M
	Rice straw	Ethanol	M
	Palm oil sludge	Biogas	M
	Distillery stillage	Biogas	M
	Rice husk	Charcoal	M

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End Use	Residue	Product	Time-base potential
2. Food and animal feeds	Rice bran and straw	Animal feeds	P
	Maize stalk, and husk	Animal feeds	P
	Maize gluten	Animal feeds	P
	Coconut meal	Animal feeds	P
	Oil palm kernel	Animal feeds	P
	Cake, stearin	Animal feeds	P
	Palm oil	Animal feeds	P
	Sugarcane bagasse	Animal feeds	P
	Rice straw	Compost (mushrooms)	P
	Sugarcane leaves	Animal feeds	P
	Cassava residues	Animal feeds	P
	Bagasse	Animal feeds	P
	Cassava Foliage	Animal feeds	P
	Molasses nitrogen	Animal feeds	P
	Edible oil refining residues	Animal feeds	P
	Rice straw (treated)	Animal feeds	I
	Bagasse (treated)	Animal feeds	I
	Rubber seed meal	Animal feeds	F
	Rubber seed oil cake	Animal feeds	F

/3.

End Use	Residue	Product	Time-base Potential
3. Fertilizers	Rice straw (burnt)	Ash	P
	Rice straw (bulk material)	Composting night soil	P
	Oil palm bunch	Ash	P
	Sugarcane filter mud	Organic manure	P
	Coconut coir	Dry manure	P
	Rice straw	Organic manure Compost	P
	Paper mill effluent (treated)	Organic manure	I
	Distillary stillage (treated)	Organic manure	I
	Sugar mill effluent (treated)	Organic manure	I
	Rubber effluent	Compost, Organic manure	I
4. Construction materials paper and handicrafts	Bagasse	Paper	P
	Rice straw	Paper	P
	Rice husk	Particle board	P
	Bagasse	Particle board	
	Rice straw	Thatch	P
		Particle board	P
	Coconut tree parts	Handicrafts	P
	Coconut stem	Timber	I
		Telephone poles	I
		Posts	I

/Rubber wood

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End Use	Residue	Product	Time-base Potential
	Rubber wood	Furniture,	I
		Rough timber	I
	Coconut trunk	Particle board	M
	Ligno-cellu-losic waste (thermodynes)	Particle board	M
	Rice husk ash	Pezsolanic material	M
5. Chemicals	Coconut shell	Activated carbon	P
	Coconut mill effluent	Vinegar	P
	Palm oil refining residue	Glycerine	P
	Rubber seed	Oil	P
	Molasses	Alcohol, citric acid, MSG, other organic acids	P
	Cassava pulp	Citric acid	P
	Palm Kernel shell	Activated carbon	I
	Ligno-cellu-losic wastes	Furfural	I
	Rice husk	Abrasives/ silica	M
	Rice straw and husk	Enzymes	M
	Ligno-cellu-losic waste	Chemical stock for plastics, textiles etc.	F

/6.

End use	Residue	Product	Time-base potential
6. <u>Water</u>	Paper mill effluent		P
	Coconut mill effluent	(Recycle,	P
	Rubber effluent	reuse	I
	Cassava effluent	or	I
	Sugar mill effluent	irrigation water)	I
	Treated oil palm		M
	Oil effluent		M
	Distillery effluent		

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REVIEW OF FAO ACTIVITIES ON AGRICULTURAL AND AGRO-INDUSTRIAL RESIDUE UTILIZATION

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REVIEW OF FAO ACTIVITIES ON AGRICULTURAL AND AGRO-INDUSTRIAL RESIDUE UTILIZATION

Introduction

The world will add at least a billion people in the next fifteen years and is expected to double its present population of about four billion after the end of the century. World food and feed production barely keep pace with population growth and reserve stocks have declined. Most developing countries are falling behind in per capita food production and cannot afford to import the additional food they require.

While large-scale efforts are being directed toward improving primary food production, there is an urgent need to consider all other means of achieving increased food supplies. The utilization of agricultural residues for human benefit is one area where strong emphasis should be placed. In recent years, the problems of agricultural and agro-industrial waste management have drawn increasing attention.

The Seminar on Residue Utilization - Mananagement of Agricultural and Agro-industrial Wastes was held in Rome in 1977 under the sponsorship of the United Nations Environment Programme and the Food and Agriculture Organization of the United Nations. The Seminar was organized jointly by these organizations as part of their responsibilities and concern for the protection of the environment and the need for increasing food supplies. The main focus of the Seminar was on the utilization of waste and residues associated with agriculture, fisheries, forestry and agro-industries. Representatives from 41 countries, 45 industrial organizations and 11 international organizations attended the Seminar.

Information Exchange

An activity on information exchange with regard to agricultural residues was initiated by FAO in 1973 when the first international

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Presented by U Thet Zin, Regional Agricultural Services Officer, FAO Regional Office, Bangkok, Thailand.

directory of institutions involved in residue utilization was published. The Compendium of Technologies and Bibliography of Agricultural Residues were later published.

With a view to assist the countries in their programmes for assessment and transfer of appropriate technologies through regional and sub-regional centres or networks, the information contained in the above publications is updated from time to time. The second edition of the World Directory of Institutions together with the Compendium of Technologies and Bibliography was published in 1978. This programme of FAO on information exchange is carried out in response to the recommendations made at the FAO/UNEP Seminar on Residue Utilization held in Rome in January 1977. These publications are available for distribution.

Agricultural Residues - Quantitative Survey. The participants at the 1977 FAO/UNEP Seminar stressed the need to develop and implement practical field programmes which would demonstrate and stimulate the fuller use of agricultural and agro-industrial residues on the national, village and farm levels. In compliance with this request FAO conducted a global identification survey inviting the views and suggestions of policy makers, planners and specialists. A comprehensive questionnaire was sent to government agencies, and national and private institutions in 128 countries, most of them from the developing countries. A total of 57 countries responded and suggested 72 proposals for establishing and implementing national research, development and demonstration projects. The majority of responses were sectorial in nature and a few of them were too vague to be of constructive use to the survey. As a whole, however, they do offer a satisfactory cross-section of the situation in the developing areas of most countries, and assist in drawing up a realistic picture of the availability of residues and of the potential for their utilization.

The first provisional report of the Survey is available. The document provides a discussion of the salient features emanating from the survey and offers some action proposals. The figures and proposals from this Survey can be used only as an indication. Any activity in a selected priority area should, however, be preceded by an on-the-spot

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and in-depth feasibility study. It is FAO's intention to increase and improve knowledge on residue availabilities by periodical updating of data. This will be done concurrently with the revising of the Directory of Institutions the Compendium of Technologies and the Bibliography, which were published last year.

Fermentation Alcohol Programme. The Workshop on Fermentation Alcohol held in Vienna in March 1979 called upon UNIDO to assist developing countries in the production of fermentation alcohol for use as fuel and chemical feedstock, and to seek the cooperation of FAO with regard to the agricultural aspects of fermentation alcohol production. The overall programme will consist mainly of (a) general studies on the economies of fermentation alcohol production from different raw materials, e.g. cane juice, molasses, cassava (b) fuel alcohol test programmes and (c) planning and establishment of new and additional capacities for production of fermentation alcohol in suitable interested developing countries.

The main contribution of FAO to this programme will be in the activities relating to assessment of (a) current cane output and potential yield increases obtainable, (b) competitive market outlets for sugar cane products and (c) potential utilization of by-products and wastes for animal feed and fertilizers.

FAO will be involved in all aspects of planning and implementing new agricultural development required for the programme.

Utilization of Rice Husks. In view of the crucial need to introduce modernized processes that will permit the utilization of rice husks as an energy source especially in the developing countries, FAO undertook a survey of available processes and equipment for burning rice husks to produce energy, leading to high-grade ash production. One of the major uses of rice husks is fuel to provide energy for rice mill operation. But the ever-increasing number of diesel and electrically-driven rice mills has largely eliminated such use except in certain areas. Consequently, large quantities of rice husks remain as unused waste material and create a significant disposal problem. The common practice has been to dump the rice husks in the open ground or into marshy rivers or creeks. The husks are also burned to facilitate removal of husk stacks from the

/mill site.

mill site. As the result of this survey, FAO was able to publish a paper entitled "Rice Husks - Conversion to Energy". This publication is available in FAO.

FAO is monitoring and promoting an initiative of a private Italian rice miller to produce producer gas from rice husk and rice husk ash for industrial purposes (mainly metallurgy). A pilot unit of new design is under construction and will be combined with converted existing combustion engines for electricity generation.

Recycling of Organic Wastes in Agriculture. A study tour was conducted in the People's Republic of China in 1977 to acquaint senior staff from developing countries with practices in the recycling of organic wastes in agriculture and to exchange experience. The study group organized under the FAO/UNDP Programme consisted of 20 participants of which 17 were from countries in Asia. The study placed special emphasis on the practical aspects and applicability of the methods observed in China.

This study was followed by another study tour on azolla propagation and small-scale bio-gas technology in China. The study took place in 1978 under a FAO/UNDP programme in cooperation with the Government of the People's Republic of China.

Utilization of organic materials to produce bio-gas and manure is not a new concept and its technology is not only confined to China. But the national approach leading to widespread proliferation of the technology the relative cheapness of bio-gas units through the use of locally available materials and communal labour and the unique basic design of the units wherein the digester acts as a gas holder are valuable points which the developing countries could learn from China.

There are FAO publications on Organic Recycling in Asia and on the reports of the above study tours to China. FAO is presently preparing a manual or handbook detailing all practical aspects of small-scale bio-gas technology in China.

Molasses Utilization. The FAO publication on molasses utilization is primarily intended for policy-makers, planners, development corporations and potential investors to help them decide on the most appropriate

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use of this valuable by-product. Molasses is one of the most widely used agro-industrial by-products but in several areas and countries it is one of the most under-utilized resources. The publication gives a condensed presentation of the different possibilities of molasses utilization. It also deals with fermentation processes.

Treating straw for animal feeding. A study was undertaken in selected countries in Asia, the Middle East and Europe to assess the physical, chemical and biological methods of treatment of straws for improvement of their feeding value. As a result of the study, recommendations were made on the practical application of various methods and for further research. In producing cereal crops, the quantity of straw that is produced is equal to or greater than the quantity of edible grain. Its utilization is, therefore, of great importance.

Availability and utilization of non-conventional feed resources in Asia

The FAO Regional Commission for Animal Production and Health in Asia, the Far East and South-west Pacific (APHCA) held an international workshop entitled "Studies on feeds and feeding of livestock and poultry in Asia, the Far East and the South-west Pacific", in the Philippines from 22 to 24 January 1980. This was followed by an Expert Group meeting on "Regional cooperation in feedstuffs development in Asia and the Pacific".

The main objectives of the Workshop in the Philippines were

1. To conduct studies on the available feeds and feeding practices in livestock production.

2. To prepare a compendium of feeds and feeding of poultry and livestock to be entitled "A Handbook on Feeds and Feeding of Livestock and Poultry for Asia, the Far East and the South-West Pacific".

3. To provide the countries in the Region an effective tool in planning and promoting joint action for the improvement of animal production.

/New Feed Resources

New Feed Resources. A variety of agro-industrial by-products are available in Asia and the Far East for use as (a) primary by-products: major ingredients forming the base of a feeding system, and (b) secondary by-products: minor ingredients supplementing the diet.

An FAO publication on new feed resources is available. It provides information on the various physical, chemical and biological methods by which the value of poor-quality roughages can be improved, how such improved materials can be incorporated into animal production systems and whether this incorporation can be remunerative. The studies include utilization of various agricultural products in the feeding systems.

List of FAO Publications on Agricultural and Agro-Industrial Residue Utilization

1. Agricultural Residues: World Directory of Institutions, FAO Agricultural Services Bulletin No. 21, Rev. I

2. Agricultural Residues: Compendium of Technologies, FAO Agricultural Services Bulletin No. 33

3. Bibliography of Agricultural Residues, FAO Agricultural Services Bulletin No. 35

4. Agricultural Residues: Quantitative Survey, FAO Agricultural Services Bulletin, Prov.

5. Residue Utilization: Management of Agricultural and Agro-Industrial Wastes. FAO/UNEP Seminar papers and documents, Rome, January 18-21, 1977, Volumes I and II

6. Les residus agricoles et leur utilisation dans certains pays du sud et du sud-est de l'aise (FAO)

7. China: Recycling of Organic Wastes in Agriculture, FAO Soils Bulletin No. 40

8. China: Azolla Propagation and Small-Scale Biogas Technology, FAO Soils Bulletin No. 41

9. Organic Recycling in Asia, FAO Soils Bulletin No. 36

10. Rice Husks - Conversion to Energy, FAO Agricultural Services Bulletin No. 31

11. Treating Straw for Animal Feeding, FAO Animal Production and Health Paper No. 10

12. Molasses Utilization, FAO Agricultural Services Bulletin No. 25

13. New Feed Resources, FAO Animal Production and Health Paper, No. 4

14. Fish Silage Production in the Indo-Pacific Region - A Feasibility Study, FAO Regional Office for Asia and the Pacific, IPFC Occ. Paper 1978/1

15. Prospects for Fish Silage in Malaysia, Sri Lanka, Bangladesh and the Philippines, FAO Regional Office for Asia and the Pacific, IPFC Occ. Paper 1979/1

16. Prospects for the Production and Utilization of Fish Silage in Thailand, FAO Regional Office for Asia and the Pacific, IPFC Occ. Paper 1979/2

UTILIZATION OF AGRICULTURAL AND AGRO-INDUSTRIAL RESIDUES

UTILIZATION OF AGRICULTURAL AND AGRO-INDUSTRIAL RESIDUES

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I INTRODUCTION

The concerns that have led to an increased focus on agricultural and agro-industrial residue utilization are many. All result from a desire for better use of existing resources. The need to meet regional and world food requirements, the increasing cost of raw materials, the desire for a satisfactory quality of the environment, and the recognition that there is a limit to world resources are among the many motives to make better use of residues resulting from agricultural production.

The United Nations Environment Programme (UNEP) and the Food and Agricultural Organization of the United Nations (FAO) have been international leaders in attempting to identify the opportunities for residue utilization and to stimulate implementation of appropriate utilization technologies and systems. In 1977, UNEP and FAO held an international seminar on "Residue Utilization - Management of Agricultural and Agro-Industrial Wastes." The major objective of the seminar was to increase awareness of the opportunities for residue utilization, to encourage governments and industry to initiate practical action programs, and to enhance continuing cooperation. The topics included a survey of the occurrence and characteristics of such residues, a review of available technology and experience with residue utilization, and discussions of the economic, political and social situations that are conducive to environmentally sound residue utilization.

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One of the recommendations of the seminar was that there should be an interchange of information on residue availability and utilization, especially on local use technologies and incentives, in different geographical regions. This workshop is a direct result of that recommendation.

The purpose of this overview is to discuss: (a) some of the factors that are important to implementation of residue utilization, (b) available knowledge about residue characteristics and utilization technology, and (c) activities that have occurred since the 1977 seminar.

II NON-TECHNICAL CONSIDERATIONS

Residues from agriculture and agro-industries can be considered as the nonproduct outputs from the growing and processing of raw agricultural products such as fruits, vegetables, meat, poultry, fish, milk, grain, and trees. These outputs are the residues of production and use that may contain material that can benefit man but whose economic values are less than the apparent cost of collection, transportation, and processing for beneficial use. They therefore are discharged as wastes. If residues can be utilized for human benefit, such as to enhance the food production, they are no longer wastes but become new resources.

In only a few situations has residue utilization been a component of waste management policy. The traditional focus has been on the treatment and disposal of wastes with the subsequent loss of material and energy resources. This one-time use and disposal of material is a result of policies developed during earlier periods of abundances of materials and energy, when there was a lesser demand on world food production and energy resources, and when there was less concern about the quality of the environment.

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The World Food Conference held in November 1974 and subsequent meetings and conferences since that time have made it clear that increasing the rate of food production, especially in developing countries, is a high priority to meet the challenge of the existing population growth and the urgent need to increase the quality of life. During the past 20 years, food production in the developing countries, inhabited by almost three-quarters of the world population, has barely kept pace with the population increase.

Developing countries are agrarian with the majority of their population in rural areas. In these areas, the source of livelihood is the production of food or fiber crops or the husbanding of animals that are adapted to local soil and climatic conditions. Such countries are interested in ways to raise incomes and living standards. Accomplishing these objectives will require an increase in food production, as well as optimum use of available resources such as currently unused residues. The residues can increase local energy supplies, be used for animal production or as fertilizers, produce microbial protein for human or animal consumption, or be processed to result in different human or animal foods.

In increasing food production we must avoid destroying the ecological base necessary to sustain it. The urgency and magnitude of more than doubling world food production by the end of this century cannot be underestimated. When considering utilization of agricultural and agro-industrial residues it is important to: (a) obtain a better understanding of the opportunities for residue utilization, (b) identify suitable technologies for residue utilization, and (c) determine acceptable institutional arrangements and incentives to achieve residue utilization.

Protein deficiencies can be severe in the developing countries. Yet with increased affluence, people demand more protein foods and spend more of their income on such foods, particularly proteins derived from animal origin. If human preference for animal protein products continues, there will be greater reliance on forages and agricultural residues as

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organic matter for ruminant feeding. This can increase food production by making use of resources that are of no direct food use to man.

The utilization of residues accomplishes reveral important objectives: (a) better use of existing resources, (b) increasing the base for food production, and (c) reduction of environmental problems caused by the accumulation and indiscriminate discharge of such residues.

More than technical solutions are needed for agricultural and agro-industrial residue utilization. The actual utilization will be determined by economic forces, regulations, regional customs and institutional and political arrangements to enhance or constrain such utilization as well as by the technological possibilities. Residue utilization must be considered as part of the total food production, delivery, and consumption system. Without such a context, residue utilization generally is viewed only as an approach to get rid of unwanted material.

Many approaches for residue utilization have been ineffective because: (a) environmentally sound and appropriate technologies for specific wastes or regions were not included, (b) implementation strategies did not function over a wide enough geographic area, (c) proper consideration of the social and political situation or the preference and desires of the people were not provided, (d) utilization was considered as a piecemeal, nonproductive approach, or (e) a sufficiently broad array of incentives was not included.

Clearly, there is no one approach that will be appropriate for all situations. An approach in one location may be linked to the availability of land, capital or equipment. This approach will not be appropriate for those who have no land. Each approach must be examined critically under the existing local or regional conditions. These conditions have to do with more than the physical environment in which the approach is to be introduced. In an agrarian society, who owns the land, the residues, and the equipment? Who tills the land for whose benefit? Who has the risk capital and related human or other resources to use with the residue utilization approach? Will the introduction of a utilization approach

/require

require subsidies, and if so, what institutions will provide them? Who will be the beneficiaries and nonbeneficiaries of the utilization approach? If the nonbeneficiaries are in the majority, what are the implications of introducing an approach that benefits the few, rather than the many, in a developing country?

These and similar questions are raised to emphasize that an innovation, such as initiation of a residue utilization approach, can be a disruptive process. The technology associated with residue utilization is not likely to be neutral. Its use can affect the micro or macro socioeconomic hierarchy and can reinforce or change the existing economic order. Individuals and organizations interested in initiating residue utilization approaches should recognize the physical, social, economic, and political patterns that exist and that will be affected by the approaches.

There are several basic steps that must be taken when considering residue utilization possibilities. The first is a clear identification of the goal or need. This could be development of energy resources, better pollution abatement, increased employment, better public health, reduction of deforestation or better utilization of the natural resource base. The appropriate approach can then be developed to utilize the existing residues to meet that need or goal. In developing an approach, it is essential to identify the institutional, organizational, managerial, collection, distribution, and marketing as well as the technological aspects of the approach.

Basically, residue utilization should be considered with optimism because of the large quantities of wastes that are produced, the obvious need to make better use of existing resources, and the successes that have occurred. However, this optimism must be tempered by caution since the result must be a usable product at an economical cost while not causing greater environmental or social problems. It makes no sense to take a waste or a residue that no one wants and turn it into a resource that no one wants.

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A second step is to delineate any existing impediments or encouragements that may be needed to develop and implement the approach being considered. These can include competing uses for the end product, type of land or residue ownership, availability of financing, societal structure, groups available to enhance implementation and utilization of the approach, managerial needs and availability of parts and repairs. Support services and market availability are keys to successful implementation and continued utilization of an approach. Too often the focus is placed primarily on the technology that is being considered.

Technology rarely is a sole constraint to residue utilization. Major constraints and problems to residue utilization lie in the non-technical aspects that assure that the technology is implemented and will continue to be used. A residue utilization system should be designed by those who will be involved in using the system. The motivation of the people is vital to achieve a viable residue utilization approach.

When considering residue utilization possibilities, it must be remembered that a farmer or a food processor is a business man. He is not a microbiologist, a chemical engineer, or a sanitary engineer. Neither are those who are likely to be involved in using the technology used for the residue utilization. The technology that is to be used should be capable of being integrated with the agricultural operation or agro-industrial facility productting the residue and with the intended use of any resultant by-product. The technology also should be able to be understood and operated by nonspecialists.

A third step is to identify and recognize the existing state of knowledge concerning residue availability and characteristics and the technology for utilization. Although many of the technologies have been utilized with one or more residues in many parts of the world, it still may be necessary to adapt the technologies to the local situation, personnel, equipment, and managerial talent and time. This may require on-site evaluations to illustrate the application of a technology to meet a desired goal. Many technologies are ready for utilization in various regions and countries after adaptation to local conditions.

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A fourth step is an understanding of the economics that are involved. With residue utilization approaches, a cost-effectiveness analysis on a strict economic basis is not easy, since it is difficult to quantify the value of better public health, better pollution abatement, decreased unemployment and other direct and indirect benefits of a residue utilization approach. Many residue utilization systems may be judged successful if they reduce the cost of current or anticipated waste treatment and disposal, or if they result in an identified public goal, even if they do not make a profit in the strict economic sense.

In summary the critical factors affecting successful residue utilization are identification of a special goal, an adequate market, suitable technology to process the residue under local conditions, and an enterprise that is socially and economically feasible.

III RESIDUE GENERATION AND CHARACTERISTICS

Understanding the potential for agricultural and agro-industrial residue utilization requires knowledge of how and why residues are generated, the characteristics of available residues, and the technology that can be considered for their utilization. Residues always have been associated with agriculture and agro-industries. However, they have become more noticeable because the natural cycles associated with agriculture have been altered significantly.

3.1 Residue Generation

The basic needs of man include food, fiber, fuel, fertilizer, and shelter. Small operations can and do cycle available resources. The basic cycle is one of the land furnishing fuel, fiber, shelter, and food in the form of crops and animals to the consumer. In a small agricultural operation, part of the residues resulting from harvesting and processing is used directly by the consumer, and the remainder is returned to the land for further utilization in additional crops. This

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approach has the benefit of proper utilization of the residues but results in a low level of agricultural productivity.

Inexpensive fossil fuel, inorganic fertilizers, and greater mechanization have been used to increase agricultural productivity and increase the food supply and standard of living in many countries. However, the consumer-land link has become weakened, and in many cases, broken. Agricultural and agro-industrial residues are no longer as well-utilized as they were in small systems and have become more apparent and of environmental concern.

The trend toward large scale agricultural and agro-industry enterprises continues in all countries. As production increases, the size of facilities and the quantities of residues at a specific site increase. The larger the production unit, the more likely there will be residues that require treatment and disposal, the larger the quantities of residues at the production site, and the increased likelihood that residue utilization possibilities can be considered.

The further from the basic cycle the situation is permitted to go, the more unbalanced the situation becomes and the greater the costs of proper residue management. The basic cycle is easier to maintain with animal production than it is with food and fiber processing. Such processing is further removed from the site of original production, and a closed cycle is less possible. Although closed cycles may not be possible throughout all agriculture, the residues should be considered as resources to be utilized rather than wastes for disposal.

Knowledge of the residue quantity and characteristics permits consideration of waste liquids for the transport of raw products, possibilities to reduce residue generation, recovery of specific components, irrigation possibilities, by-product development, and use of residues as a fertilizer. Therefore, an important initial step in residue utilization is to determine the quantity, quality, and source of the residues actually produced. If the residue utilization possibilities in an agro-industry

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are to be evaluated, a water and mass balance on the processes used will identify the sources and quantities of the residues that are generated.

3.2 Residue Characteristics

The feasibility of residue utilization depends on the characteristics of the residue, the quantity that is realistically available, the continuity of supply, value of the residue as a useful by-product or raw material for other products, and the cost of residue collection and transport. For the most part, available information on the characteristics of agricultural and agro-industrial residues is woefully inadequate. Generally the information known about residues relates to pollutional characteristics, such as BOD, COD, TKN, suspended solids and grease, rather than those more appropriate for utilization. More detailed information must be available to adequately assess the potential of many residue utilization possibilities.

The following indicates the type of information that is needed to assess whether it is feasible to consider utilization of a part or all of the residues: detailed characteristics, seasonality of production, geographical distribution, and generation per unit of production. Only infrequently is such information available. Yet it is the very information that is needed to judge the feasibility of residue utilization technologies. For example, if one wishes to consider energy production, one needs to know the energy content of the residue, the quantity of residue produced, and its continuing availability.

Assuming that information on the quantity, availability, and general characteristics of the residues is known or obtainable, the potential utilization possibilities can be assessed. At that time, data on specific characteristics pertinent to such possibilities can be obtained. These could include combustible energy content, fertilizer value, metabolizable energy, digestibility, organic matter and similar related information.

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4.1 General

There are many technologies that can be considered for utilization of agricultural and agro-industrial residues. In general, the technologies can be grouped according to their intended goal such as to: (a) enhance food production through use of the residues as fertilizers, soil conditioners, or for irrigation, (b) produce fuel through direct combustion of the residues or through production of methane, (c) increase animal production through use of the residues as animal feed, or (d) enhance production of chemicals or biochemicals.

The FAO compendium of technologies[1/] provides detailed information on the characteristics of certain agricultural and agro-industrial residues, the process technologies that have been used, the resultant products, and references describing where the technology has been utilized. Table 1 summarizes potential utilization technologies and the types of residue that have been used with the technologies.

Additional examples of how agricultural and agro-industrial residues have been used include: fruit and vegetable wastes utilized as animal feed, paper made from straw, chemicals extracted from organic residues, and fish meal from seafood processing waste. Several industries such as soap, leather, and animal feed manufacturing utilize meat packing wastes. Biochemicals such as hormones, vitamins, and enzymes also have been produced from packinghouse residues. Animal manure has been used as soil conditioner, as an animal feed supplement, for fertilizer, and to produce methane.

Other opportunities for the utilization of agro-industrial residues occur in the urban and horticultural sectors. Solids separated from

/Table 1

1/ "Compendium of Technologies Used in the Treatment of Residue of Agriculture, Fisheries, Forestry and Related Industries" FAO Agricultural Services Bulletin 33 (Rome, 1978)

Table 1 Examples of Utilization Technologies for Agricultural and Agro-Industrial Residues

Technologies	Common Residues Used with the Technologies
Energy Generation	
- methane generation	- animal manures, food processing liquids and solids, crop residues
- pyrolysis	- animal manures, wood processing residue
- burning	- animal manures, wood, forestry residues, bagasse, nut husks
Food Production	
- single cell protein production	- waste sulfite liquor, fruit and vegetable processing residues
- animal feed	- fish silage, whey, processed animal manures, food processing residues
- fish production	- animal manures, food processing residues
By-Product Production	
- oil recovery	- seeds, fish processing residues
- compost	- food processing residues, animal manures, crop residues
- pulp and particle board	- forestry and wood processing residues, bagasse
- glue, gelatin, fats	- tannery residues, meat processing residues
- alcohol	- food processing residues, whey
Fertilizers	- animal manures, food processing residues
Irrigation	- agro-industrial wastewaters

manure and food processing wastes are being composted and used for plant growth media, soil conditioners for parks and gardens, and animal bedding.

While the above and other methods can be used for residue utilization, they rarely solve an entire waste problem since the material produced or removed may be only a small component of the original residue. There will be secondary residues requiring treatment or disposal. Such residues will be either portions of the original residue or residues generated in the utilization process. Thus residue utilization should not be considered as a panacea or substitute for waste management. The goal of "total utilization" has not been achieved with most utilization approaches.

Any residue utilization process will be subjected to the same pollution control measures that governed the process producing the initial residues. Provisions must be made for acceptable ecological and economic disposal of secondary residues from any residue utilization process.

Information about the characteristics and available quantities of agricultural and agro-industrial residues is fundamental to the development of feasible residue utilization systems. Technology that may have been successful with certain residues may be less successful with other residues, unless the technology is modified to accommodate the characteristics of the residues being considered. Agricultural and agro-industrial residues vary in quantity and quality. Residues from food processing generally are low strength and high volume liquids; those from livestock operations tend to be high strength and low volume solids or slurries; and those from crop and forest production tend to be drier, bulky, and broadly dispersed solids. Solid residues also are generated in food processing and livestock operations.

Agricultural and agro-industrial residues are organic and biodegradable. Utilization technology must either use the residues rapidly, or the residues must be stored under conditions that do not cause spoilage or render the residues unsuitable for processing to the desired end product.

Identification of the residue sources within an agro-industry processing plant can be important, since it provides information for in-plant

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separation of the residues. Separation of residues at the source is a major technological means of assisting residue utilization. Such separation generally results in less contaminated and more concentrated residues and can enhance the technical and economic utilization of the separated fractions.

In addition to the specific residue characteristics that must be known when identifying the feasibility of a particular technology, there is additional information that must be obtained related to:

- availability—time, location, seasonality, and ability to store the wastes
- convertibility—handling, separation, transportation, and physical processing of the residues and end products of the utilization technology
- use of the end product--markets, demand and rate of growth of demand, storability, seasonality of use

Few really novel residue utilization technologies exist. Many have been tried at the laboratory, pilot plant, and full scale levels with at least one residue. When considering residue utilization technology possibilities, it is important to avoid reinventing the wheel. Available information should be critically analyzed to learn from and adapt the knowledge and experience that does exist. A key to the application of suitable residue utilization technologies is the ability to modify technologies to the local conditions and to the characteristics of the specific residue.

4.2 Energy Generation

Most of the population in developing countries relies on wood, animal manure, straw, and animal and human power to meet their basic energy needs. It is possible to produce additional energy from agricultural and agro-industrial residues for use in developing countries. Both biological and thermochemical processes are available for conversion of residues to fuel. The biological approaches include production of

/biogas

biogas and production of ethanol. The thermochemical approaches include pyrolysis to produce oils, char, and gases. Dry organic residues also can be used directly as a fuel.

4.2.1 Biogas

The interest in nonfossil fuel energy has focused increasing attention on the production of methane from the anaerobic fermentation of organic residues. Table 2 indicates some of the agricultural and agro-industrial residues that have been used or that have the potential for methane generation.

By using residues for methane generation, the additional value of the methane can be gained while realizing other benefits. The original nutrients in the digested material can be returned to the soil as a fertilizer and to improve organic matter content. In many developing countries, locally collected firewood is used for village heating. The collection of such wood has denuded forest and agricultural land, increased erosion and flood problems, and decreased the agricultural base for crop production.

Where methane is produced for domestic or farm use from available organic wastes, the drudgery of collecting wood, dried dung, or crop residues and the smoke generated by burning of these materials has been reduced. In addition, when applied to the fields, the stabilized wastes from the methane digestion unit have helped increase agricultural yields, control erosion, and maintain desirable soil characteristics. Methane generation is a process that helps conserve rather than lose nitrogen and other important components in the wastes.

The end result of applying digested sludge on soils is the same as that resulting from the application of any other organic matter. The digested solids can improve soil physical properties such as aeration, increase the moisture-holding capacity, increase the cation exchange capacity, and improve water infiltration. The sludge can serve as a source of nutrients for the crops grown on the soil. When animal and

/ Table 2

Table 2 Agricultural and Agro-Industrial Residues Having Potential for Methane Generation

- Animal wastes including bedding, wasted feed, and poultry litter
- Crop wastes such as sugarcane trash, weeds, straw, spoiled fodder, and forest litter, especially if mixed with nitrogen-containing residues
- Slaughterhouse wastes, fishery wastes, leather and wool wastes
- By-products from agro-industry such as oil cakes, fruit and vegetable processing residues, sugar production press mud, sawdust, tobacco wastes, distillery residues, rice bran
- Aquatic growth such as marine algae, sea weeds, and water hyacinths

/agricultural

agricultural wastes are used for methane generation, there is little likelihood that any items in the sludge will cause adverse conditions to the crops or to the animals fed crops grown on land where the digested solids are applied.

Other benefits accruing from methane generation include those obtained from using the methane for heating, cooking, lighting, refrigerating, pumping irrigation water, or running other power units. There may also be improved public health, agricultural productivity increases, and increased employment. The use of village scale digesters can provide a sanitary means of human waste disposal that might otherwise be lacking.

Methane generation is likely to have its greatest use in areas remote from fossil fuels or other energy sources, where available fuels are better used for other purposes, and for small villages and activities where methane is used at or close to the production site.

The process of anaerobic digestion is a natural one which occurs whenever organic matter is microbially decomposed out of contact with air. During the anaerobic digestion of most organic wastes, gases containing 60 to 75 per cent methane can be produced when consistently high rates of digestion are maintained. Approximately 8 to 9 cubic feet of gas can be produced per pound of volatile organic matter added to the digester when easily biodegradable wastes are digested. Lower gas production rates result when less biodegradable wastes are digested. The production of methane from waste is centuries old and the applicable technology is well known.

In countries where energy supplies have been hampered by low natural abundance or inadequate distribution, methane has been generated from available residues to meet ex.sting needs. For examjle, the process was used in several countries during and following World War II, several thousand units are operative in parts of Asia using pig manure and by-products from individually owned and cooperative pig farms, and in India, crop residues and cow dung are used in family and village operated units.

/Key

Key items in the successful operation of a methane generator are: (a) the biodegradability of the organic matter, (b) acceptance by the potential user, (c) ability to store the gas or use it when produced, (d) adequate raw material to meet production requirements, and (e) suitable operational control and maintenance.

The biodegradable fraction of agricultural and agro-industrial residues will vary depending upon their source and how they were generated and handled prior to digestion. For example, only 40 to 50% of the volatile solids in dairy manure may be biodegradable and available to produce methane. To use anaerobic digestion most effectively, inert material such as sand and dirt should not be included, and fresh wastes should be utilized.

An important aspect to be considered with anaerobic digestion is that the total volume of digested material that remains and must be handled for final disposal is equal to or greater than the amount of residues added to the digester. Any increase will be due to the liquid that must be added to the process to dilute dry material and obtain a mixable solids concentration. Although considerable solids decomposition occurs when methane is generated, little reduction of the total digester volume occurs.

4.2.2 Ethanol Production

A number of cellulose, starch and sugar containing residues can be converted to ethanol. Production of ethanol by fermentation involves the following steps:

- availability of a suitable and continuing supply of raw, fermentable material
- conversion of the raw material to a medium suitable for fermentation by yeast
- fermentation of the medium to alcohol
- recovery and purification of the ethanol
- treatment, disposal, or utilization of the fermentation residue

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The availability of a suitable and continuing supply of fermentable material is necessary because there appears to be little value in operating an alcohol plant intermittently or at less than full capacity. If the raw material must be stored to assure continuity of alcohol production, it should be stored in such a manner as to avoid microbial decomposition.

Conversion of the raw material to a fermentable medium can be simple for residues such as molasses. Starch-containing residues need to be cooked and the starch hydrolyzed to sugars by acid or enzymes. More resistant materials such as wood will require chemical treatment prior to fermentation.

Purification of the ethanol is done by distillation which involves a significant energy input and cost. The alcohol production residues can be treated by anaerobic digestion to produce methane which may be used in the production system. An energy and cost balance should be performed on any proposed ethanol production approach to ascertain that a positive energy balance results, i.e., that the energy output exceeds that used in the process and in treating or utilizing the resultant residues.

4.2.3 Pyrolysis

Pyrolysis is the high temperature decomposition of organics in the absence of oxygen. Reactor temperatures range above 900°C and high pressures are common. The products are ash, oils, and gases such as hydrogen, water, carbon dioxide, methane and ethylene. In general, over 90% of the heat value of the residue is retained in the products of the process.

The process has been in use for decades to produce methanol, acetic acid, and turpentine from wood with recovery of the charcoal. Pyrolysis has been investigated as a potential process for egg farm wastes (dead birds, litter; manure), cow manure, rice bran, and pine bark.

/Pyrolysis

Pyrolysis is a high technology process requiring continuity of raw material, reasonable consistency in raw material characteristics, and adequate technical operation and maintenance.

4.3 Land Application

An important way to utilize liquid and solid agricultural and agro-industrial residues is to apply them to the land and benefit from them as fertilizers, soil conditioners, and for irrigation. The advantages of returning organic residues to the land include: (a) less dependence on increasingly costly chemical fertilizers, (b) improved soil structure, and (c) reduced need for the application of micronutrients.

4.3.1 Fertilizers

Before the availability of mineral fertilizers, animal manures, human wastes, and composts were the primary source of crop nutrients. While the availability of mineral fertilizers has resulted in a lesser interest in organic wastes as fertilizers, the principles of such use remain valid and can be employed for increased crop production.

Certain residues, especially those from livestock production and processing can be useful as a fertilizer. Residues of vegetative origin, such as fruit and vegetable processing wastes and crop residues, can increase the organic content of the soil and add to its fertility. Organic residues from agriculture contain most of the elements needed for plant growth and can supply nutrients through decomposition at a rate comparable to that needed by growing plants.

Land that continues to be used for crop production without the addition of fertilizers will have the available nutrients seriously depleted. Frequent addition of nutrient containing residues can maintain soil fertility and crop production.

Nitrogen is one of the important components of organic residues that make them possibilities as fertilizers. The nitrogen in such residues should be better utilized. In the United States of America, greater than 50% of the nitrogen in organic residues such as animal manures is lost using current handling procedures. On a nationwide basis,

/nitrogen

nitrogen losses from animal manures in the U.S. may approach four million tons annually. The percentage losses can be higher in countries that make little attempt to store and use animal manures as part of crop production. If organic agricultural and agro-industrial residues can be used as fertilizers and soil conditioners, the base for food production in all countries, but especially the developing countries, can be enhanced.

In general, one of the best ways to utilize organic residues is to return them to cropland and reincorporate them in the soil. The feasibility of this approach is influenced by factors such as: (a) the economics of transporting the residues to the land and incorporating them in the soil, (b) the transmission of plant pathogens, and (c) the need to avoid exceeding the capacity of the land to assimilate the residues. The proper residue application rates must be determined by local conditions such as precipitation patterns, natural soil fertility, crop needs, quantity of needed nutrients, and factors in the residues that may inhibit crop growth.

Crops which seem to be the most suitable for effective utilization of roganic residues such as manure are crops which have prolonged growth periods, crops which use large amounts of fertilizers, and fodder and grain crops such as clover-grass mixtures, potatoes, silage corn, and other silage grains. Manures from modern animal production units are a valuable organic fertilizer and soil conditioner returning nutrients and organic substances to the land, increasing soil fertility and productivity, and possibly improving the ecological balance.

4.3.2 Composting

Composting offers another opportunity to recover and utilize the nutrients and soil conditioning factors in agricultural and agro-industry residues, in urban organic refuse, and in other organic industrial residues.

Composting is an aerobic, biological process in which organic residues are converted into humus by the numerous soil organisms. These

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include micro-organisms such as bacteria, fungi, and protozoa and invertebrates such as nematodes, worms, and insects. Nutrients are conserved compositing. Some are absorbed on the fiberous matter in the residues and others are incorporated in the humic material formed by the organisms. When compost is applied to the soil, these nutrients are released slowly and made available to plants over long periods.

The factors that affect the composting process include moisture content, nitrogen, phosphorus, potassium and other minerals, aeration, carbon/nitrogen ratio, pH, and temperature.

Water content plays an important role in composting. The proper water content of compost is about 50 to 70%. Compost should feel damp, not wet. Composting generates heat and water is driven off during the process. If insufficient water is present, the compost will dry and decomposition will slow. With an excess of water, nutrients may be leached and undesirable anaerobic conditions can occur.

Since composting is an aerobic process, all of the composting material should have access to air. This can be accomplished through physical turning or incorporation of air passages in the mass with stalks, pipes or tiles.

A pH range of 6 to 8 is desirable for optimum growth of the organisms in the composting process. During composting, organic acids are produced which can reduce the pH and the rate of composting. Alkaline material such as lime, mollusk shells, egg shell, crushed bone or wood ashes can be added to neutralize the acids and maintain an efficient composting rate.

The composting organisms require a certain amount of nitrogen for their growth. A suitable carbon to nitrogen (C/N) ratio for composting is about 20 to 30 to 1. If the ratio is less than 15:1, nitrogen can be lost from the process as ammonia. If an ammonia odor is noticeable, this indicates that the C/N ratio is too low and carbon sources such as shredded leaves or paper or sawdust should be added to

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the composting material. If the ratio is greater than 30:1, there may be insufficient nitrogen for the organisms and the composting rate will decrease. Residues high in nitrogen, such as manures, can be added if inadequate nitrogen is a problem.

Considerable heat is generated as the micro-organisms decompose the organic residues. Temperatures can reach 40 to 60°C. With these temperatures, human and livestock pathogens and parasites are rendered non-infective or are killed. High temperatures are enhanced by proper moisture, aeration, and C/N conditions and by small residue particle size and intermittent mixing.

Composting is complete when the temperature of the composting material returns to ambient temperatures, and when the compost is finely divided dark in color and has an earthy odor. The compost not only will provide nutrients but will enhance the physical structure and water holding capacity of the soil.

Composting has been used in many countries on both a small and large scale. The technical know-how is available for village level and agro-industrial use of the process for organic residues.

4.3.3 Irrigation

Application of agricultural and agro-industrial wastewaters to land, either for crop irrigation or for groundwater recharge, can be a very effective way of utilizing this material. This approach is best utilized in areas with a deficit of available water during part or all of the year.

Agriculture is a major user of water, primarily for irrigation and for food and fiber processing. Irrigation of cropland with wastewaters offers possibilities for both water reclamation and utilization of the nutrients and organics in the wastewaters. The microbial and plant action in the plant-soil filter can remove organics, most inorganics, and bacteria. Upon reaching the groundwater, the wastewater has lost its identify and has been renovated. The nutrients and organics can be incorporated in the crop grown on the irrigated site.

/Considerable

Considerable use also has been made of municipal wastewater and sewage sludge for agricultural purposes. Adequately treated municipal wastewater can be used for the irrigation of pasture land, cotton, and grain crops. Application of sewage effluent to land will further treat the effluent, thus augmenting groundwater supplies, in addition to the effluent being utilized as a source of irrigation water. Such a practice also reduces the pollution load to streams of the area.

Land disposal of residues partially restores the nutrient cycle of food and crops which is interrupted by the transport, treatment and disposal of food and crop wastes to surface waters. Such an approach often is less expensive than other waste treatment and disposal alternatives. To utilize wastewater irrigation as a long term viable alternative, the concentration of salts in the root zone of the crops must be kept below detrimental levels.

Irrigation has been used to dispose of wastewaters from dairy and milk processing wastewaters, food processing and canning wastewaters, as well as treated municipal sewage and to enhance the food production potential of the irrigated land.

4.4 Animal Feed

The traditional method of increasing livestock production by supplementing forage and pasture with grains and protein concentrates may not meet future meat protein needs. Use of the grain and protein for human food will compete with such use for animal feed. In addition, the conversion of many available residues directly to human food presents problems when the source of the residue is not food grade. These problems may be circumvented by utilizing residues to feed domesticated animals.

Many organic residues such as paunch manure, fish meal, oil seed meal, whey, and vegetable processing residues can be used directly for animal feeds. Indirect approaches to use agricultural residues for animal feed include refeeding of processed animal manures, production of insect protein, and production of fish.

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In the production of many food crops, residues suitable for conversion to animal feed equal or greatly exceed the food actually consumed. Only about 60% of root and tuber crops, 40% of grain crops, 15% of oilseed crops and 10% of sugar crops are consumed directly for human food. The remainder of these crops have a potential for use as animal feed.

The quantities of these residues are large. Recent estimates indicate that cereal straw production in Asia is over 600 million tons of straw. The residues from cassava, bananas, citrus fruits and coffee are estimated to be about 124 million tons in Asia, Africa, and Latin America. These regions also produce an estimated 83 million tons of sugar cane residues. In additibn, there are about 3500 million head of all types of domesticated livestock in these three regions. The manure from these animals has the potential for various types of utilization as part of the animal feed cycle.

Crop residues have a high fiber content and are low in protein, starch or fat. Cell walls of straw primarily are lignin, cellulose, and hemicellulose. The digestibility of the lignin-cellulose material is inversely related to the amount of lignin in the crop residue. Rice straw has a silica content of up to 15% which can adversely affect digestion.

Physical disruption of the straw structure by grinding can increase digestibility. Alkali treatment using sodium hydroxide, calcium hydroxide, and ammonia has been found effective in increasing ruminant digestibility of straw.

4.4.1 Fermentation

Many fermentation processes can improve the nutritional value of agricultural and agro-industrial residues for animal feed. In these processes, micro-organisms decompose the organic matter and convert cellulose into protein.

/Ensilation

Ensilation has long been a method of improving feed quality and conserving crop residues for animal feeds. It can be conducted in simple or complex facilities and can be applied to a wide range of residues. Lactobacilli play a predominant role in ensiling where they rapidly acidify the mass to repress the growth of undesirable microorganisms. The lactic acid that is produced imparts a desirable odor and taste to the mass. Stimulation of lactic acid production can be achieved either by addition of selected organisms or by providing a suitable medium in which such organisms can develop. In terms of nutritional value of the feed produced, ensiling affects primarily the nitrogen-free extract substrates. The soluble carbohydrates are reduced and fatty acid content is increased.

An ensilage process known as "wastelage" has been used to process animal manures into animal feed. The wastelage system consists of blending 40% wet manure, at about 70-80% moisture, with dry standard feed ingredients followed by ensiling the mixture for over 10 days. Fermentation occurs in a silo and the pH decreases to near 4.0. This acidic condition inhibits most biological activity. The resultant wastelage has been fed to cattle and other animals successfully.

Food processing residues are able to be microbially converted to animal feed since they can contain a balanced concentration of organic and inorganic nutrients and there rarely are toxic materials present. A major problem is the seasonality of waste availability. Capital expenditures for microbial processing facilities are usually based on year round operation.

Many examples illustrate residue utilization using microorganisms. These include processes to produce fermented food and single cell protein (SCP) and nonspecific processes such as biological treatment processes that involve generation of microbial protein. The following indicate available information on such processes.

There are a variety of fermentable carbohydrate sources for SCP. Residues such as waste sulfite liquor, whey, starch, and molasses may be used to produce biomass by conventional fermentation

/technology.

In the production of many food crops, residues suitable for conversion to animal feed equal or greatly exceed the food actually consumed. Only about 60% of root and tuber crops, 40% of grain crops, 15% of oilseed crops and 10% of sugar crops are consumed directly for human food. The remainder of these crops have a potential for use as

technology. Cellulose is the most abundant carbohydrate raw material and is available in waste paper, bagasse, wood pulp, sawdust, and hay.

The Pekilo process is a process to produce feed protein from carbohydrate residues through fermentation with the microfungus Paecilomyces variotii. The research leading to this process was initiated at the Finnish Pulp and Paper Research Institute. The Pekilo protein is a safe, high-quality feed ingredient approved by Finnish authorities for animal feed. The protein and fat content of the dried product is 5560% and 2-4% of the dry matter respectively. It has been estimated that a yield of 200 pounds of cells containing 60% protein could be produced per ton of pulp. Feeding studies on rats indicated the cell material was palatable, nontoxic, and an excellent protein supplement.

4.4.2 Direct Refeeding

Many agro-industry residues, especially those derived from food processing, contain the same constituents as the original product. A number of such residues have been used directly as animal feeds. These include pineapple bran, bagasses, bananas, ramie, coffee wastes, mustard wastes, citrus pulp, grapeseed meal and olive cake. Most have been fed to ruminants at levels of 5-20% of the total feed with no adverse effects.

The possibility of recycling animal manure directly as a feed ingredient for animals to provide a source of nutrients while minimizing potential waste pollution has received considerable attention. A common conclusion is that if nutritional principles are followed, a portion of animal manure can be used as an animal feed supplement. Animal manure and poultry litter may be an economic source of nutrients and should be recognized as a possible feed ingredient. To be handled in this manner, such materials would be subject to feed control laws in the same manner as are other feed ingredients. In research evaluations, feeding processed animal manures has not altered the taste or quality of meat, milk, or eggs. Potential transfer of organisms can be controlled by dehydration, drying, composting, ensiling, or fermentation.

/In general,

In general, the nutritive value of incorporating animal manure in animal feed rations is greater if the manures of single stomached animals are added to the feed ration of ruminants, and if the manures are treated chem.cally before being added to feed rations.

Available information on manure digestibilities and chemical characteristics indicates that they may be considered best as low energy-containing supplements of nitrogen and minerals, especially for wastes from animals that exist primarily on forage and hay. Levels of manures in animal rations reported as successful have ranged from 10 to 25% of the ration dry matter content.

4.5 Other Approaches

In addition to the above approaches, there are many others that could be considered. The intent of this section is not to provide details of all the available processes but to illustrate additional approaches that can be considered for improved residue utilization.

Approaches to residue utilization generally focus on utilization of existing residues. However, such approaches also should focus on reducing the quantities of residues that are generated. These reductions can increase usable food supplies. It has been estimated that if the food losses that occur between harvest and consumption could be decreased by 30 to 50%, the available food supply could be increased by 10 to 15%. This would have the effect of reducing residues while better utilizing available resources. In doing so, valuable animal and human food would not occur as waste and food production would be increased.

Food processing operations can provide examples of how process modifications can improve residye utilization. New mechanical deboning processes have the potential of increasing the amount of available red meat by 3 to 4% thus reducing waste production and better utilizing available animal products for food production. Blood contains approximately 17% protein and the total recovery of this material could result in the production of over 180 million kilograms of protein in the U.S. alone.

/Cheese

Cheese plants can be modified to include equipment to recover and process whey which is the liquid by-product of cheese manufacturing. Most of the whey is discharged to waste treatment plants or to the environment thereby increasing the cost of the cheese production and the costs of water pollution control. Whey can be used as a partial animal feed, a feed supplement, a starting material for chemical production such as alcohol, and as a growth medium for microorganisms to produce organic chemicals. Whey powder can be blended with basic food materials to produce new and/or less expensive foods such as process cheese food, fruit sherbets, custards, and bakery goods.

Fish processing also offers opportunities for residue utilization. Fish represent a largely untapped source of large quantities of protein, particularly parts of fish or whole fish being under-utilized or wasted. At the present time, more than two-thirds of the harvested seafood is not being utilized directly as human food.

Little of the fish which enter a processing plant need remain as wastes. Stickwater (water which has been in close contact with the fish and contains considerable organics) and the nonedible portions can be collected and processed into products such as fish meal or fish solubles. Solids can be ground, cooked and pressed to remove valuable liquids and oils before the residue is dried. This fish meal can be bagged and marketed for different uses including fertilizer and animal feed additives. The liquids and oils from the processing of the cooked solids can be concentrated along with stickwater and ground viscera in a solubles plant. After concentration, the solubles can be marketed as animal feed and for other uses.

V EXAMPLES

5.1 Introduction

Many examples can be provided that illustrate how agricultural and agro-industrial residues have been utilized. A number has been

/identified

identified briefly in the previous section. This section will present specific examples that appear to be particularly relevant to the countries attending this workshop.

5.2 Fish Silage

About 20 million tons of fish per year are processed into fish meal. Modern fish meal production is capital intensive and technologically complex. An economic operation will occur where large volumes of fish are available on a regular basis. Other alternatives will have to be used where smaller volumes of fish and fish by-products exist.

Fish wastage is a major problem throughout the world with losses estimated to be about 4 to 5 million tons per year. Conversion of this material to animal feed by acid ensilage represents an important method of utilization.

Fish silage can be a simple and inexpensive means of preserving waste fish for animal feed. Fish silage is a liquid product made from acid and fish or parts of fish. Inorganic or organic acids can be used or the production of lactic acid can be encuraged by mixing a carbohydrate source with the fish and inoculating with lactic acid producing microorganisms. Optimal liquefaction can occur with 3% formic acid addition.

Compared to fish meal production, fish silage requires little capital investment, little sophisticated technology, and is comparatively cheap to produce. The process can be used at both the individual and industry levels. The silage product may be used in a liquid or dried form. With conventional feeds, liquid feeding systems have advantages. The process also can be applied to animal by-products such as animal and poultry offal.

Fish silage production on an industrial scale occurs in Denmark and Poland where a total of about 40,000 tons was produced in 1974. In both countries, the silage is used to supplement pig feed. Experimental fish silage production and animal feeding trials are underway in Indonesia, Malaysia, Singapore, and Thailand. Fish silage produced on a village or

/industrial

industrial scale could help satisfy the increasing demand for animal protein in these countries, possibly reduce fish meal imports, help remove a pollution problem, and make fuller use of marine resources.

To accomplish greater production and utilization of fish silage, there will have to be a more integrated approach between the fishing and livestock industries, feeding trials should be conducted to identify appropriate local animal feeds, and the corrosive nature of the silage should be controlled.

5.3 Algae Production

The conversion of solar energy into cellular protein can be a potential way of increasing animal feed production. Research in several countries has shown that human and animal wastewaters can be excellent substrates for algae production. The algae are capable of photosynthesis to release oxygen which helps support the bacterial and other micro-organisms that decompose the organic matter in the wastewater. This symbiotic action stabilizes the organic waste and converts the nutrients into algal proteins. Algae contain about 45 to 65% crude protein. In terms of protein production, algae can produce many times more kilograms of protein per hectare than can soybeans or corn.

The types of algae which can be grown are highly variable depending upon local climatic conditions, wastewater characteristics, and operational characteristics. Those commonly encountered include Chlorella, Oscillatoria, and Scenedesmus. Harvesting of small, single-celled algae can be a constraint to large scale algae production.

Postharvest processing of waste-grown algae can range from sun-drying to drum-drying. Sun-drying is a low energy process, but the digestibility of sun-dried algae is lower than drum-dried algae. Algae utilization in fish, poultry and pig feeding has been demonstrated in Philippines, Singapore, and Israel.

Algae most suited for efficient large scale algae production are the blue green algae Spirulina maxima and Spirulina or Arthospira platensis. These have been identified as having considerable potential

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as an animal or human food since the cell protein quality is good and is toxin free. These algae are large and prefer a highly alkaline medium (pH 10-11). The large size facilitates harvesting by screens or cloth. These algae have been utilized for food in Mexico and Chad for many years.

5.4 Aquaculture

The use of organic residues for feeding fish has occurred for centuries. Pond culture of fish has several advantages for residue utilization. Fish have a density approximately that of water and need less energy than land animals to move and support themselves. This increases the efficiency of converting residues to fish growth. Once a system is properly stocked, the only external requirement is minimum management and sunshine for photosynthesis. Fish ponds can be productive with minimum labor, low capital input and can be placed on land unsuitable for agriculture.

A part of the fish food developed in a pond results from the nutrients in the residues. This food consists of small organisms, plants, and animals. Due to the small size of this material, harvest by man is difficult. However, if fish are stocked at the correct density and species combination, the fish can harvest organisms efficiently thus converting nutrients to fish protein.

Many organic residues can be used in aquaculture, such as oilseed cake, distillary residues, and slaughterhouse and food processing residues. Animal manures can serve as an indirect food by enhancing the production of natural aquatic food in fish ponds. The bacteria that decompose the manures serve as food for protozoa, zooplankton, and higher organisms which are consumed by the fish.

Intensively manured fish ponds have produced 15 to 30 kg. fish/ha/day with cow or chicken manure and nitrogen and phosphate as the only nutritional inputs to the pond. This compares to fish yields of 1 to 5 kg/ha/day with no external fertilization and 10 to 15 kg/ha/day with only chemical fertilizers. A polyculture of common carp, tilapia, and silver carp were stocked in these ponds. Swine manures also have been used in controlled fish production.

/Polyculture

Polyculture is necessary to obtain high fish production levels since each species feeds on different organisms. Use of polyculture also prohibits a build-up of unused food and metabolic products that can inhibits a build-up of unused food and metabolic products that can inhibit growth and require flushing or water recycling systems.

Polyculture systems can be integrated with livestock production. Manures can drop directly and continuously into the fish pond or can be transported and added continually. Polycultures can involve many types of aquatic life. The most common use multiple species of fish. Such species include: (a) those that feed on aquatic vegetation and terrestrial residues such as food processing residues, (b) those that feed on zooplankton and other aquatic life, and (c) those that feed on benthic material.

The production achieved by polyculture is dependent upon climate, quality of the organic residues, aeration, temperature, management practices, and types, numbers and sizes of the fishes that are stocked. With intensive management and optimum conditions, high production rates of over 15,000 kg fish/ha/year can be obtained. Lower rates, in the range of 2000-5000 kg/ha/yr, are more common in less intensive systems.

Fish polyculture systems utilizing organic residues are in operation in many European and Asian countries. The technology for aquaculture using organic agricultural and agro-industrial residues is available. Capital and qualified management and labor are needed for increased use of this approach.

VI INTERNATIONAL ACTIVITIES

As indicated earlier, UNEP and FAO have held an international seminar dealing with the utilization of residues from agriculture and agro-industry[2/]. Working groups analyzed the residue utilization

/opportunities

2/ UNEP/FAO Seminar on Residue Utilization Management of Agricultural and Agro-industrial Wastes, FAO (Rome, January 1977).

opportunities for sugar, oils and oilseeds, cereals, fruits and vegetables, animal production, fish harvesting and processing, starchy roots and tubers, cellulosic residues and single cell protein. The seminar recommendations included :

- Each country or region should establish or have available center to coordinate and carry out the research, development and other investigations necessary for the evaluation and success of possible residue utilization approaches.
- Each country and industry should establish strategies and priorities for residue utilization that reflect realistic social, economic, and technical goals.
- There should be an interchange of information between similar regions, especially on local use technologies and incentives.
- Greater incentives, such as strict pollution control regulations, waste discharge taxation, and subsidies to enhance utilization, should be provided for residue utilization.
- There should be experimentation with technology adapted to local situations.
- Governments and non-governmental organizations, including industry, should establish development and field projects to illustrate the possibilities of utilizing the residues in their region or country.

UNEP, particularly through its Industry Programme based in Paris, and FAO, through its headquarters in Rome, are continuing to provide information on residue utilization to all interested parties. Of particular interest to individuals interested in utilization of agricultural and agro-industrial residues is the World Directory of Institutions[3/]

/involved

3/ "World Directory of Institutions Concerned with Residues of Agriculture, Fisheries, Forestry and Related Industries", FAO Agricultural Services Bulletin 21 (Rome, 1978).

involved in such utilization and the Compendium of Technologies[4/] that can be used for utilization of these residues. The Directory and the Compendium provide a broad base of information on these topics.

More recently a quantitative survey of agricultural residues and their utilization has been prepared by FAO[5/]. This survey attempted to analyze the utilization of agricultural and agro-industrial residues throughout the world. Responses were received from 57 countries. Profiles of the availability, actual uses, and proposed utilization of such residues in 45 countries are presented in the bulletin.

Table 3 summarizes the major quantities, current constraints to utilization, and the type of assistance that might be needed for enhanced utilization for the seven Asian countries included in the survey. It is interesting to note that nontechnical constraints and assistance are identified to a greater extent than technical ones.

The survey indicated that the characteristics, volume, and extent of availability of the residues are seldom known or able to be reasonably approximated. The survey also suggested that the pattern of actual residue utilization appeared to be fairly uniform. Bulky agricultural residues such as straw, stalks, and tops are usually burned in the field, left on the spot or plowed under, except for the fraction that is used as fuel in the rice mills and the cane sugar mills. Wet residues such as sugar beet leaves can be fed to livestock or stored as silage, but the bulk is wasted.

Animal manure is used as organic fertilizer at the farmstead. Manure from large scale poultry farms and piggeries creates environmental problems since its disposal is not easy unless such large units are combined with crop raising in the immediate vicinity.

Slaughterhouse residues such as blood, paunch contents and conde ed carcasses or parts of them are completely wasted because of

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4/ "Compendium of Technologies Used in the Treatment of Residues of Agriculture, Fisheries, Forestry and Related Industries, op. cit.

5/ "Agricultural Residues and Quantitative Survey", FAO Agricultural Services Bulletin (Prov.), (Romt, 1979).

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small scale and unhygienic operations. Effluents and other residues of processing industries such as palm oil, olives,meat, fish, coffee, breweries, are mostly wasted.

Forestry logging, sawmill and wood processing industry residues are mostly burned or used as fuel. In only a few cases are they utilized for press board, particle board or to produce small articles for household or other use.

In addition to the efforts of international organizations, many individual countries have established activities and programmes that emphasize residue utilization. As an example, in Canada, the International Development Research Centre in Ottawa has significant focus on this topic. In the United States, the National Academy of Science has several committees summarizing existing information on the topic. Similar efforts are underway atinstitutions in Thailand, India, Japan, Philippines, England, and other countries.

There is considerable interest in identifying ways to utilize residues from agricultural and other industries throughout the world. The decade of the eighties will see a major expansion in that interest and a growth in the number and size of experimental and full-scale systems to illustrate such utilization.

VII SUMMARY

Resource consdrvation will become an increasingly important philosophy for individuals, industries, and governments in the next decades. The greater cost of energy, the need to meet enlarged world food requirements, and the perception that there is a limit to world resources will result in broadened adoption of such a philosophy. Utilization of ricultural and agro-industrial residues will be a key component of resource conservation efforts.

/Table 3

Table 3 Major Residues, Constraints to Utilization and Requested Assistance for Better Utilization in Asian Countries*

Country	Major Residues	Constraints	Assistance Requested
Burma	- cereal straw, husks, cobs - fruit and vegetable stems and husks - sugarcane bagasse - oilseed stalks and leaves	- collection and transport - shortage of capital - lack of local technology	- technical information - technical advice - R/D projects
Indonesia	- rice straw and husks - logging residues - sawmill and plywood residues - fish processing residues - oilseed and nut processing residues - sugarcane bagasse	- suitable technologies - economic incentives - markets - capital	- technical information - specialist advice - training of local personnel - R/D projects
Malaysia	- rice straw and husks - cocoa pod husks - oil palm press fiber and oil sludge	- suitable and economical technologies - capital - managerial initiative	- technical
Nepal	- maize stalks and cobs	- capital - suitable technology	- feasibility studies
Pakistan	- urban market residues	- managerial initiative	- R/D projects
Philippines	- animal manures - rice straw and husks - corn stubble - sawmill residues - coconut water and coir cust	- collection and transport - suitable technologies - economic incentives	- technical information - specialist advice - training of local personnel - R/D studies - market studies

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Table 3 continued

Country	Major Residues	Constraints	Assistance Requested
Republic of Korea	- animal manures - rice straw and husks - fish canning residues	- suitable technologies - waste management incentives at the local level - limited market demand	- financial assistance - training of personnel - R/D projects
Sri Lanka	- rice husk and straw - coconut shells, water and	- collection and transport - suitable technologies - market outlets	- technical information - financial assistance
Thailand	- animal manures - forestry residues - sawmill residues - rice straw - sugarcane residues	- collection and transport - lack of assured markets - economic incentives - managerial initiatives - suitable technologies	- financial assistance - training in technology and marketing - R/D equipment - R/D projects

Residue utilization must be considered with optimism because of the obvious need for resource conservation and the quantities of residues that exist. However, the optimism must be tempered by caution, since the result must be a usable product at an economical cost while not causing greater environmental or social problems.

The feasibility of residue utilization depends on the characteristics of the residue, the amount that realistically is available on a consistent basis, cost of residue collection and transport, and the availability of a market for the resultant product. Greater attention should be paid to these aspects since detailed information about these topics is crucial to the success of any residue utilization effort.

The successful application of residue utilization technology will require the selection, modification, transfer and adaption of technologies to local conditions. The ability of local manpower to operate and service the various technolog.cal approaches requires careful evaluation. Where necessary, educational programmes may be required to assure qualified manpower.

There is no one best approach to residue utilization. In each situation, the possible alternatives need careful evaluation with the most appropriate single technology or combination of technologies chosen to provide desired environmental, economic, and social objectives. These objectives are important since even when the costs of recovery, including return from sales, cannot be brought below the disposal cost, there may be sufficient other benefits to make government incentives for resource recovery a rational and useful policy.

Many countries and international organizations have active programmes to investigate, evaluate, and encourage residue utilization and other resource conservation efforts. The next decade will se e an expansion of such programmes and a growth of demonstration and operating residue utilization systems. The information in the FAO survey of agricultural residues[6/] should be used to guide national, regional, and

/international

6/ "Agricultural Residues and Quantitative Survey", *op. cit.*

international efforts dealing with the utilization of agricultural and agro-industrial residues.

The pressures for better resource conservation are increasing, the need for better residue utilization exists, and many applicable technologies are available. The challenge is to bring about a change in personal and public philosophy toward residue utilization and to provide the appropriate incentives to stimulate greater and broader action.

POLLUTION CONTROL AND MANAGEMENT
OF AGRO-INDUSTRIAL WASTES

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I INTRODUCTION

In the most industrialized countries, the major environmental concerns revolve around controlling air and water pollution and waste disposal, because the problems in these areas have reached alarming proportions. There is, however, less recognition of the more fundamental preventive measures which seek to remove the causes of degradation, rather than concentrating on the effects.

The protection of the environment must be considered in its proper perspective for the developing countries of the world. The great importance and urgency of economic development in these countries should not be overlooked. The recommendation for the protection of the environment may not be the first priority for countries that still need to solve their more basic needs, such as food, shelter, education and health.

Two-thirds of mankind, who live in the developing regions of the world, do not share the same concern about their environment as the other one-third who live in the more affluent regions. They have little interest in the purity of the air they breathe, the freshness of the waters of their lakes and rivers, the natural beauty of their mountains. They have more immediate problems - the struggle for the bare necessities of life - which is becoming increasingly difficult for them because of the rapid growth of population. What interest can such people have in questions of environment? The governments that represent them are preoccupied with the pressing problem of raising their standards of living and of providing their basic needs. The highest priority is given to economic progress. How can they be asked to adopt measures such as preventing industrial waste from polluting rivers, restricting the use of insecticides like DDT, controlling the emission of smoke and fumes from chimney stacks, and stringent land use controls which will increase the cost of economic development? This must be kept in mind when recommending measures which the developing countries should take to protect their environment. Recommendations that curtail or restrict economic progress and dampen the rising expectations of the people of developing countries for a better life would be unacceptable to most governments of these countries.

But some action to achieve compatible industrial technology will produce immediate benefits and is essential to safeguard the environment for future generations. This can best be achieved by establishing priorities for the protection of the environment, beginning with those aspects which will not impede economic development and which, at the same time, are vital for the future well-being of inhabitants. For example, the location of industries to minimize environmental impact and to be more compatible with human needs and amenities, the protection of the watersheds, the tropical rain-forests which ensure pure supplies of fresh water in the rivers and in the lakes; the protection of natural parks and game reserves; the protection of places of historical archeological interest; the protection of places of tourist interest like lakes, mountains and unspoiled sea beaches; and even the protection of land that will be needed for future urban settlement.

When these countries have generated sufficient economic growth, they will be enabled to turn to more sophisticated measures to prevent pollution and the destruction of the environment. But by taking steps <u>now</u> to safeguard the <u>vital</u> features of the environment, they would have laid a very useful framework for building up a national environmental policy. Regional action should be taken by developing countries to protect some of these essential features of the environment.

Asian developing countries are dominantly agricultural, and crop productions are becoming increasingly important, generating significant amounts of agricultural and agro-industrial residues each year. Residues may be defined as those by-products which, for economic or social reasons, are not fully utilized within the confines of the production unit and are allowed to burden the natural environment. The large quantity of wastes generated by agricultural and agro-industrial operations and specific environmental problems that have resulted from these activities have amended to the management of agricultural and agro-industrial residues and by-products. Reclamation from residues is, of course, not a new idea for man has always attempted to reclaim waste in many diverse ways, whenever it is attractive to do so. However, recovery from waste attracted a growing interest during the past two decades or so, and although there are probably many reasons why this has happened, two of the main influencing factors are certainly: (1) the continuing growth in the generation of wastes, the disposal of which poses management and environmental problems; (2) a growing awareness that primary or virgin resources are in many cases in finite supply, coupled with recent sharp increases in the price of energy and some other natural resources. In spite of this growth in interest in resource recovery, as manifested in intensive research and development into recovery and substantial expenditure on test and demonstration plants, there remains the question of economical viability of the recovered by-product. This aspect will be treated with more details in other papers of this Seminar.

The residues from agriculture and agro-industry are mainly organic and can be solid, slurry or liquid form. The term "residue utilisation" is rather vague and needs clarification. It is generally understood that residue refers to solid or slurry form of waste, readily amenable to resource recovery. The liquid form refers to wastewater as the result of agro-industrial operations, and requires minimum treatment to comply with standards of acceptable levels of discharge. In some cases, resource recovery from residues produces second generation wastewater which also needs to be treated in accordance with environmental standards. The ultimate resource recovery of wastewater would be reuse or recycle of water after reasonable treatment of wastewater. This paper focuses the discussion on the liquid form of 5 agro-industrial residues in the ESCAP region: tapioca, palm oil, rubber, sugar, and coconut. The environmental impacts of their discharges will be assessed. Recommendation of rational and effective waste treatment processes for these wastes will be brought about. Finally some preventive measures will be suggested in order to prevent the sinking of the environment by uncontrolled discharges of these agro-industrial wastes.

II ENVIRONMENTAL IMPACT OF WASTE DISCHARGES

Discharge of waste materials alters the quality of the receiving water to a greater or lesser degree and is of concern when such alterations interfere with legitimate water uses. Conservative pollutants are dispersed and distributed in the water body under the influences of primarily hydrodynamic and diffusive forces. If the weight of non-degradable material in a waste is known, it is relatively easy to determine the concentration over a time in a river or lake since dilution is the predominant process when the substance is in solution. But the stochastic nature of stream flows and unpredictable variations in industrial waste discharges may sometimes make the procedure difficult. The problem is more complicated in the case of tidal estuaries and ground water aquifers because of their complex hydraulic characteristics. Suspended sediments will settle out in lakes and reservoirs and to some degree in flowing streams, particularly in sections where there is a major decrease in stream velocity.

Determination of the spatial and temporal distribution of degradable wastes is considerably more difficult than for non-degradable wastes because of physical, chemical and biological changes which take place in addition to dilution and dispersion. In the following discussion attention is concentrated on organic wastes emanating from the processing of tapioca, sugar cane, palm oil, rubber and coconut, being increasingly important crops and significant agro-industries in South and Southeast Asia of ESCAP region. In areas where these crops are processed, their wastes contribute significantly to stream pollution. In general, food processing requires large quantities of water, and significant amounts of wastewaters are released. Heavy pollution of land and streams by these wastes gives rise to obnoxious odours in the neighbourhood of factories, which is a nuisance to passers-by and residents. In addition high solids content of the wastes make them detrimental to flora and fauna of streams to which they are discharged. Receiving streams become aesthetically unpleasant and their usefulness for irrigation, and fishing is considerably limited. Even in cases where the receiving stream affords high dilution, the waste still imposes limitations in its use as a source of potable water supply; urban and rural people are often seriously affected by uncontrolled discharges of these wastewaters. Problems are magnified if the receiving streams afford little or no dilution during dry weather.

With such discharges the primary concern is the effect of their degradation on water quality, in particular the dissolved oxygen concentration in the receiving waters. On discharge to water body, the biodegradable organic matter in wastewaters is broken down by microorganisms, principally bacteria. This creates an oxygen demand which will be supplied by the dissolved oxygen (DO) in the water. As a result the DO concentration is decreased. As the organic matter is generally depleted the oxygen requirement decreases and dissolved oxygen concentration in the receiving water is restored through reaeration. The rate at which oxygen demand is exerted and the rate of reaeration will govern the profile of oxygen downstream of the discharge. Any other factor which results in addition or removal of organic matter or oxygen will also affect the oxygen balance. Table 2.1 includes oxygen sources and sinks which have to be taken into account in water quality modelling. Fig. 2.1 is a typical example of a simple dissolved oxygen sag curve for a single source of pollution on a non-tidal watercourse. Point C, the critical dissolved oxygen level, may be at any level between complete oxygen saturation and zero dissolved oxygen and it is at this location where stream conditions are worst. Other things being equal factors that reduce the rate of exertion of oxygen demand lengthen and flatten the oxygen sag, while those that accelerate BOD exertion have the reverse effect.

Agro-industrial wastes can penetrate the groundwater and alter its quality. There is limited information on the amount of agro-industrial contaminants that enter subsurface waters under given disposal practices and on the change in groundwater quality caused by various agro-industrial contaminants. In addition, there is a scarcity of adequate groundwater monitoring programmes to investigate these factors. Water from shallow

Table 2.1 Oxygen Sources and Sinks

Oxygen Sinks	Carbonaceous Oxidation	- Oxidation of carbon compounds.
	Nitrification	- Oxidation of nitrogen compounds.
	Benthal Demand	- Benthal decomposition and resuspension
	Plant Respiration	- Plankton and aquatic weed respiration
Oxygen Sources	Atmospheric Reaeration	- Diffusion of atmospheric oxygen through surface.
	Photosynthetic Oxygen Production	- Plant photosynthesis
	Bottom Deposit	- Deposition of organic matter on bed

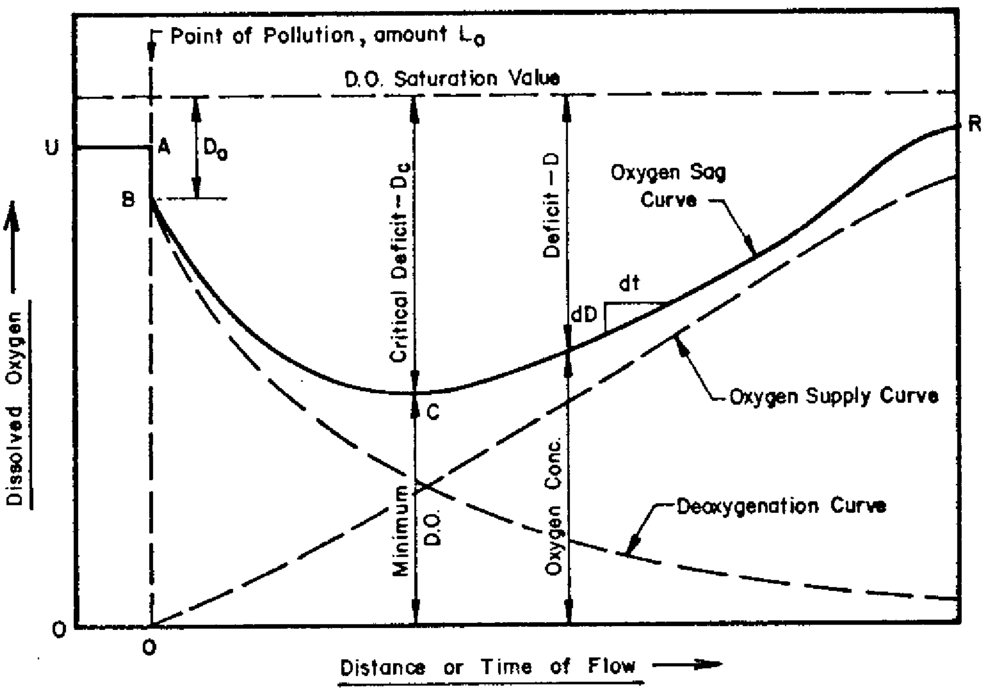

Fig. 2.1 Dissolved Oxygen Sag Curve

wells is more likely to contain contaminants than water from deeper wells. In choosing sites for the land disposal of wastes, the possibi-

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lity of groundwater contamination should receive thorough investigation.

The causes and concerns of agro-industrial waste treatment and disposal are analogous to the environmental problems caused by people. Aggregations of people in cities and the development of large-scale industrial operations have caused the air and water pollution as well as health problems which are receiving increasing awereness. Pollution potential index for developing countries, being a function of population density and per caput income in a country, must provide indication of the present and future magnitude of a country's generation of pollution as well as the indication of how bad an individual city's position can be.

III WASTEWATER CHARACTERISTICS AND RECOMMENDED TREATMENTS - CASE STUDIES

Knowledge of wastewater characteristics of the above-mentioned crops is fundamental to the development of rational waste management systems. The processes to extract starch from tapioca roots, sugar from sugar cane, oil from oil palms, latex concentrate from rubber, desiccated coco from coconut shells, all require large quantities of water, and significant amounts of wastewaters are released. These wastewaters are characterised by their high dissolved organic solid contents, amenable to biological treatment.

Identification of the waste sources within a processing plant provides information for in-plant separation of the waste streams in the plant, for reuse of the less contaminated waters, and for changes in processes that produce large quantities and/or concentrated wastes. Knowledge of the waste characteristics permits consideration of reuse of waste liquids for the transport of raw products, recovery of specific waste components, irrigation, by-product development, and fertiliser value.

Industries waste discharges are often related to the weight of product produced. This is a useful form of expression when the effects of process or product changes are being studied. Another way of expressing industrial pollution loads is to work out a population equivalent for the wastes discharged. For organic waste discharges in an Asian city, the total BOD discharged per day divided by 56.8 g would give the equivalent population which would discharge the same amount of BOD. Thus, using this method it may be determined that a factory in an unpopulated rural setting is equivalent in terms of polluting capacity to a large town. For example, a sugar cane processing factory in rural Thailand was found to have a population equivalent of 60,000 with respect to BOD discharged.

This chapter puts accent on production processes of the crops under study, sources of wastes, wastewater characteristics and treatment alternatives. For this purpose, it is appropriate to discuss individual crop cases.

3.1 Tapioca Starch Industry

Tapioca is grown in most tropical areas of the world and is also known as cassava and manioc. The root of the plant contains 20 per cent or more starch in a cellulose matrix. Tapioca starch is in particular demand for sizing paper or fibres and is used in the food industry.

In Thailand, two grades of tapioca starch are produced by two types of processes, although the quality of the final product is similar in both cases. Initially, the tapioca roots pass through the same processing in both grades of factory, namely dry removal of sand and clay, root washing and rasping. Thereafter, first-grade starch is produced using centrifugation, filtration and spray drying; this process is capital intensive and uses less labour and more water than the other process. By contrast, very little mechanization is utilized in second-grade starch factories, which are usually small private-enterprise plants; these installations are not capital intensive but use very simple methods of separation by cloth filtration, gravity settling, decanting and drying on heated concrete slabs. Flow diagrams for both types of process are given in Figure 3.1 and wastewater streams are shown.

a. Tapioca Starch Wastewater Characteristics

The combined wastewater from tapioca starch production is mainly composed of root washwater and either the starch supernatant decanted from sedimentation basins or the separator wastewater, depending upon whether a second-grade or first-grade starch factory is being considered. First-grade and second-grade factories in Thailand commonly process in the order of 200 and 30 metric tonnes of tapioca root per day, respectively, and release wastewaters with unit mass emission rates (UMER values) as shown in Table 3.1. Designations A, B, C and D refer to wastewater sources shown in Figure 3.1.

The characteristics of tapioca starch wastewaters are summarized in Table 3.2. Root washwater contains high settleable solids, mainly

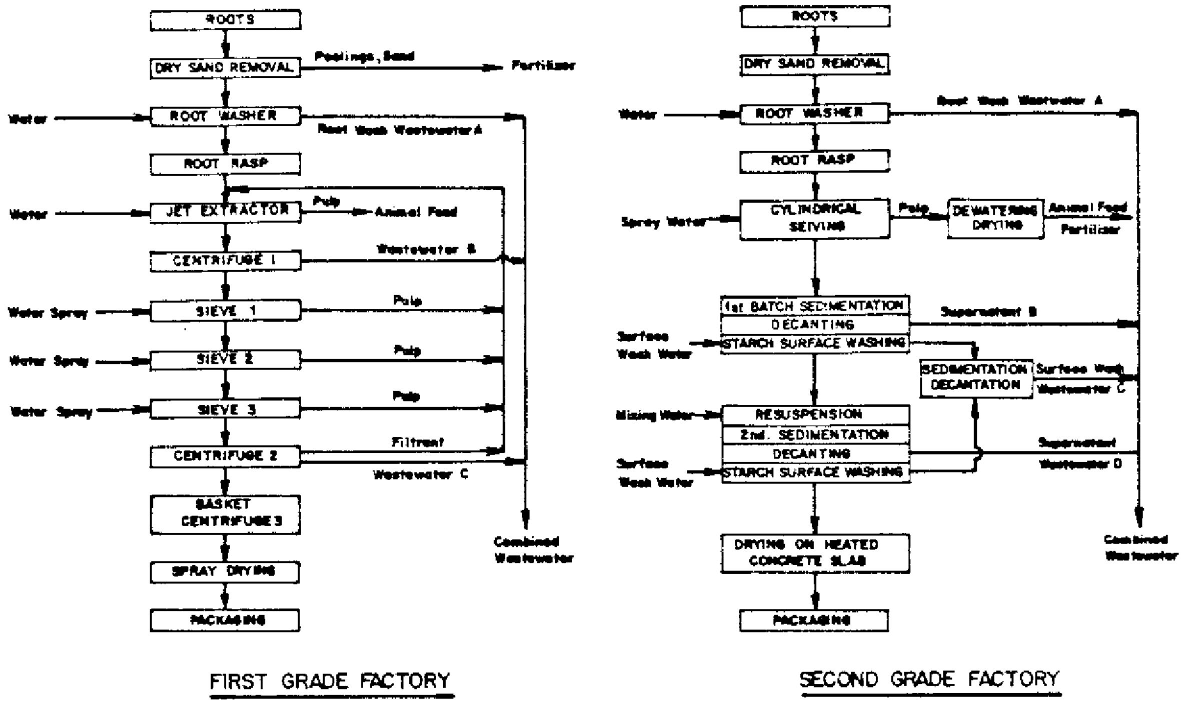

Fig. 3.1 Tapioca Starch Processing in Thailand.

Table 3.1 UMER Values of Tapioca Starch Wastewater in g/kg Root

Characteristic	Wastewater				
	A	B	C	D	Combined
	1st-Grade Factory				
COD	0.69	55.2	6.0		6.20
BOD_5	0.33	26.5	2.9		29.8
Suspended Solids	0.54	10.5	3.7		15.7
Dissolved Solids	4.91	46.3	9.6		60.8
	2nd-Grade Factory (Average of 2 Plants)				
BOD_5	0.8	28.5	1.5		30.4
Total Solids	2.2	45.2	1.9		49.5
Suspended Solids	0.8	11.3	1.3		13.4
	2nd-Grade Factory (One Plant)				
BOD_5	1.8	44.8	2.1	2.1	48.7
Total Solids	3.1	102.8	2.2	2.2	109.2
Suspended Solids	3.1	83.5	0.6	0.6	87.2

Table 3.2 Characteristics of Tapioca Starch Wastewaters (After Charin, 1968 and Yothin, 1975)

Characteristic, mg/l (except as indicated)	2nd-Grade Starch Wastewater				1st-Grade Starch Wastewater		
	Washwater		Supernatant		Plant A		Plant B
	Range	Mean	Range	Mean	Separator Waste	Washwater	Combined Wastewater
BOD_5	300-2490	1192	1720- 6820	4148	3000- 4000	200-1700	5550- 7400
COD	613-6110	2696	4704-10010	7584	3100-13900	2000-4850	13300-19500
Suspended Solids	290-4240	1880	470- 1710	855	1480- 8400	400-6100	1970- 3850
NH_3 - N	0-7.8	1.9	1.2- 35.0	15.6	0- 4.7	0-1.1	0
Org - N	0-67.2	32.1	4.3-109.2	68.8	19.0-38.9	14.5-18.2	86.0- 115
Phosphorus	0-6.0	3.6	0-10.5	6.6	5.6- 8.5	1.2-1.3	0
T.D.S.	32-6956	2749	3892-16392	9388	-	-	-
pH	3-4.6	4.2	2.6- 4.0	3.4	3.4- 4.2	4.2-7.1	3.8- 5.2
D.O.	0-4.9	2.7	0- 2.7	1.0	0	0.6-5.3	0
Acidity	-	-	-	-	668- 860	19-223	135- 1010
Settleable Solids, mg/l	-	-	-	-	60- 200	10-100	48- 115
Temperature, °C	-	-	-	-	28.5- 33	28- 31	30- 31

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sand and clay particles from the raw roots. The combined waste is acidic in nature, its pH ranging from 3.8 to 5.2, resulting from the addition of sulphuric acid in the extraction process and also from the release of some prussic acid by the tapioca roots (Knight, 1969). Tapioca starch wastewaters are highly organic but have relatively low nitrogen and phosphorus concentrations. Thanh and Wu (1975) reported the ratio of soluble BOD_5 to soluble COD in the settled separator waste as 0.6-0.8, indicating that the waste is biologically degradable. It is likely that biological treatment methods will be most economical for this organic waste and the high BOD and COD concentrations suggest that anaerobic biological processes will be effective.

b. Tapioca Starch Wastewater Treatment

Substantial research work on this topic has been conducted at the Asian Institute of Technology, Bangkok, Thailand, as reported by Pescod and Thanh (1977).

Recommended Approach to Treatment

Both first-grade and second-grade factories discharge two major wastewaters which are: washwater, from root washing (wastewater A in Figure 1); and separator waste, from jet extraction and channel separation (wastewaters B and C in Figure 3.1, 1st Grade Factory), or starch supernatant decanted from sedimentation basins (wastewaters B, C, D in Figure 3.1, 2nd Grade Factory). Water usage in factories depends on plant capacity and type and on the availability of water. Second-grade factories use less water and release less wastewater than first-grade factories, 6.3 l/kg root processed compared with 7.7 l/kg (McGarry et al., 1973), and process less root each day. Washwater makes up from 7 to 16 per cent of the total combined waste flow in both types of tapioca starch plant.

Washwater usually has lower organic strength and flow rate and is much less a problem in treatment than separator or starch supernatant waste. It may be treated in combination with the separator or starch supernatant waste but normally it will be advantageous to treat separately.

If the combined factory waste is to be treated, the processes outlined herein for separator or starch supernatant waste will apply equally to the combined waste.

Root Washwater Contains mainly cork cells, sand and clay particles which are derived from washing raw roots. During the dry season, when washwater BOD_5 values from a first-grade factory were found to range from 200-500 mg/l (Jesuitas, 1966), plain sedimentation produced an effluent suitable for reuse in root washing, a desirable objective in any tapioca starch factory. During the wet season, when waste BOD_5 increased to about 1,700 mg/l in the same first-grade plant, it is suggested that chemical coagulation followed by sedimentation is likely to produce a treated waste suitable for recycling. If chemical treatment is not effective the washwater must be treated in combination with separator waste. The same recommendations will be applicable to washwater from second-grade tapioca starch plants.

Separator Waste or Starch Supernatant, which are very similar in quality, pose the greatest problem in treatment. Plain sedimentation will remove gross suspended solids and reduce BOD_5 and COD. Settled separator or starch supernatant wastes, although high in BOD_5 and COD, are readily degradable using biological means. Their high BOD_5 and COD suggest that anaerobic biological processes will be effective. Anaerobic ponds followed by facultative oxidation ponds will be appropriate low-cost processes for handling this waste in developing countries. Use of anaerobic ponds may be eliminate the necessity for constructing primary sedimentation tanks, although the latter might well be economic if the settled solids are saleable for animal feed.

Primary Sedimentation

Jesuitas (1966) carried out sedimentation studies on separator waste and found that 91 and 96 per cent of the suspended solids deposited in 15 minutes and 1 hour, respectively. After 15 minutes, reductions in BOD_5 and COD of 74 and 80 per cent were observed. These removals were further increased after one hour of sedimentation but insignificant additional removals resulted when the detention time was prolonged to 2 hours. Sedimentation seems to be an essential first-stage process in treatment of this waste and, since starch supernatant is similar in character to separator waste, similar results can be expected. Combined tapioca starch wastewater is also amenable to primary treatment by sedimentation.

Anaerobic Treatment

Anaerobic ponds will generally be the simplest and cheapest anaerobic form of treatment for this wastewater but will not achieve an effluent quality suitable for discharge to a receiving water and a final aerobic stage of treatment will be necessary.

Yothin (1975) tested a series of pilot-scale ponds (Fig. 3.2) with only the first-stage anaerobic. It can be seen in Table 3.3 that very high BOD_5, COD and suspended solids removals were obtained in the anaerobic pond (P_1). These were achieved even without nutrient supplementation and with a highly saline waste, caused by the use of a groundwater supply near the sea. Detention time in this anaerobic pond was 17.42 days at average flow and a substantial increase in pH occurred in passage of the waste through the pond.

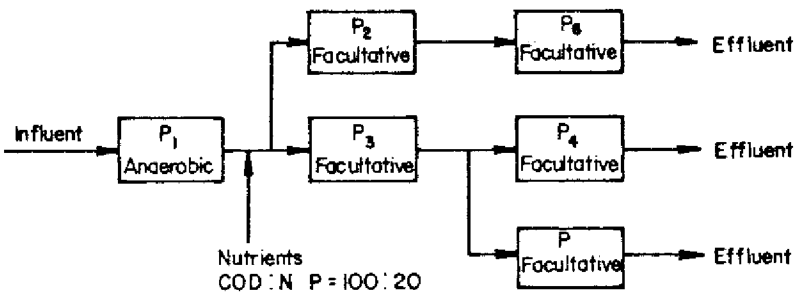

Fig. 3.2 Pilot-Scale Ponds Used by Yothin (1975)

Oxidation Pond Systems and Aerated Lagoons

Facultative Oxidation Ponds Oxidation ponds have long been known to be low-cost and reliable but take up significant areas of land. Facultative ponds may be used as sole treatment for a waste or, as might be more applicable in the case of tapioca starch wastes, as secondary treatment after first stage anaerobic ponds.

Yothin (1975) also used facultative ponds and it can be seen in Table 3.3 that, after the high BOD_5 and COD removals in the first stage anaerobic pond, subsequent pond loadings and removals were lower. There was no significant difference between the performance of the three third-stage ponds, and hence it seems that there is no benefit in loading the third-stage pond below 112 kg BOD_5/ha day (100 lb BOD_5/acre day). It is probable that the efficiencies of 2nd and 3rd stage facultative ponds were seriously affected by the saline nature of the waste.

Uddin (1970) also studied facultative ponds as third stage treatment of tapioca starch separator waste, after two stages of anaerobic pond. He operated two facultative ponds in parallel, each receiving effluent from two anaerobic ponds loaded at 6,900 kg BOD_5/ha day (6,160 lb BOD_5/acre day) in the first-stage and 7,350 kg BOD_5/ha day (6,570 kg BOD_5/ha day) in the second-stage, with detention times of 5 and 2 days, respectively. The facultative ponds were operated at BOD_5 loadings of 1,070 kg/ha day (960 lb/acre day) and 650 kg/ha day (580 lb/acre day) with detention periods of 5.52 and 9.25 days; BOD_5 removal efficiencies were, respectively, 40 and 47.5 per cent. However, when the facultative pond effluents were filtered before determining BOD_5, the removal efficiencies were 67.6 and 75.8 per cent indicating that significant portions of BOD_5 in the effluents were due to suspended solids, mainly algae. Influent BOD_5 averaged 990 mg/l and so the effluents from third-stage ponds were still not suitable for discharge to surface waters and another stage of facultative ponds would probably be necessary. However, performance was better than in the previous case, probably because of the non-saline character of the waste.

Aerated Lagoons When the simplicity and low-cost of oxidation ponds are desirable but land is scarce or costly it is possible to use the pond type of construction for higher rate aerobic treatment. This aerated lagoon system would be appropriate for the final aerobic treatment of tapioca starch waste after anaerobic ponds.

Table 3.3 Performance of 3-Stage Oxidation Pond System Treating Tapioca Starch Waste (After Yothin, 1975)

Item	Unit	Influent	Effluent					
			P_1	P_2	P_3	P_4	P_5	P_6
Pond Stage Areal Loading	kg BOD /ha day		1320	336	562	81	40	90
	lb BOD /acre day		6524	300	500	72	36	80
Detention	days		17.42	16	8	32.7	65.4	28.6
COD	mg/l	8816	816	660	675	282	263	237
COD Removal	%		90.7	19.1	17.3	58.2	61.0	64.1
BOD_5	mg/l	5200	448.5	342	287.8	115.8	73.1	51.7
BOD_5 Removal	%		91.4	23.7	35.9	59.8	74.6	84.9
SS	mg/l	1299	182.5	230	194	155	136	130
SS Removal	%		86	26.0	0	20.1	29.9	43.5
pH		3	6.4	6.85	6.85	6.8	7.05	6.9

Yothin (1975) operated an experimental fully-mixed aerated lagoon in treating the effluent from an anaerobic pond and his operational parameters and results are summarized in Table 3.4. The aerated lagoon allowed a reduced total detention time and yet gave a satisfactory level of final effluent, even with the saline waste encountered.

Table 3.4 Aerated Lagoon Performance in Tapioca Starch Wastewater Treatment (After Yothin, 1975)

Lagoon	Detention Days	Total COD, mg/l		Efft. Soluble COD, mg/l	SS, mg/l		Total COD Removal, %	MLSS, mg/l
		Inft.	Efft.		Inft.	Efft.		
1	2	930	299	260	132	48	72	112
2	4	1376	248	205	210	92	85.1	576
3	8	1376	137	105	210	124	90.2	768

The main advantage of aerated lagoons over oxidation ponds is that land requirements are considerably reduced. However, in Yothin's comparison, the facultative pond system and the anaerobic pond aerated lagoon system were closely competitive on the basis of monthly running costs taking into account land rental (at U.S.$3,000 per hectare per year). Flow diagrams of the alternative systems are shown in Fig. 3.3 for a combined tapioca starch wastewater flow rate of 500 m^3/day and mean BOD_5 concentration of 2,740 mg/l. Yothin estimated that the running costs of the anaerobic/facultative pond (alternative A) and the anaerobic pond/aerated lagoon (alternative B) would be approximately 1.85 and 0.87 per cent, respectively, of the value of the starch produced by the factory.

Rotating Biological Drum Filter

In recent years, the rotating biological filter has been developed for treating wastewaters from small communities and industrial plants. Pescod and Nair (1972) reported on the applicability of this form of treatment in tropical developing countries and it would appear to be suitable for tapioca starch wastes. This type of treatment could be adopted as the sole biological process or it could be used after anaerobic ponds where land availability is limited.

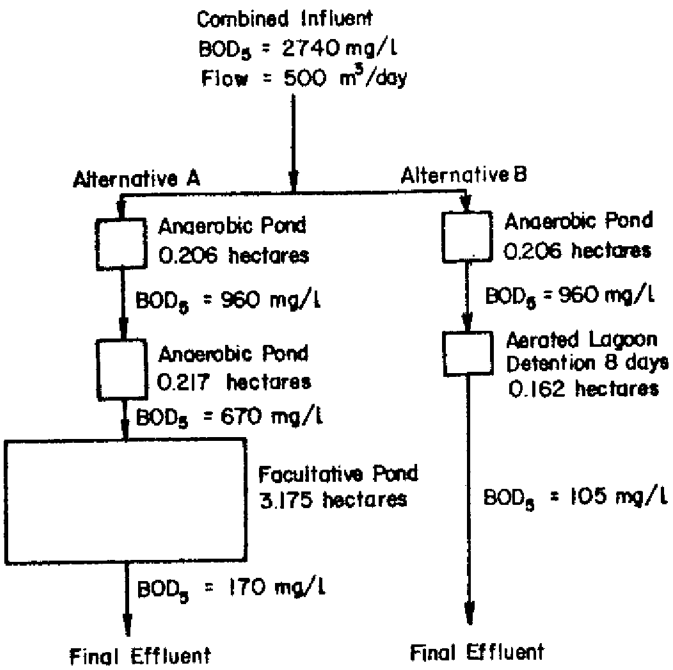

Fig. 3.3 Flow Diagram Comparing two Alternative Treatment Systems (after Yothin, 1975)

Enayatullah (1975) tested the performance of a rotating biological filter, the Euromatic Bio-Drum[1/], in treating combined tapioca starch wastewater with BOD_5 and COD in the ranges 4,068-6,098 mg/l and 5,414-8,323 mg/l, respectively. He carried out his study at the same factory as Yothin, using the highly saline wastewater. The bio-drum was 60 cm in diameter and 40 cm long and comprised a heavy wire-mesh drum filled with equal sized 38 mm plastic spheres (2,463 spheres, offering a specific surface area of 157.9 m^2/m^3) and six 1-ℓ volume water lifts which were fixed around the circumference of the drum. The drum was mounted on a horizontal shaft and rotational speed was fixed at 11 rpm. The bio-drum floated on a 300 ℓ square tank and was submerged slightly less than 50 per cent.

1/ Supplied by the European Plastic Machinery Manufacturing Co., Ltd., Copenhagen, Denmark.

Fig. 3.4 shows average BOD_5 and COD removals versus BOD_5 and COD loadings applied per units as indicated. Increase in organic loading gave decreased efficiency but a relatively high efficiency of removal was possible within the maximum detention of 16 hours tested. However, with the very high influent BOD_5 and COD, it is probable that four or more equal-sized stages of bio-drum would be necessary to achieve a suitable effluent quality but even this would give a substantial reduction in detention time from those of the other alternatives discussed. The rotating biological filter seems to be a very promising treatment process for tapioca starch wastewaters. It is simple and highly flexible in operation and takes up very little space. In those locations where land is either not available or costly, this system will have many advantages for small agro-industrial factories.

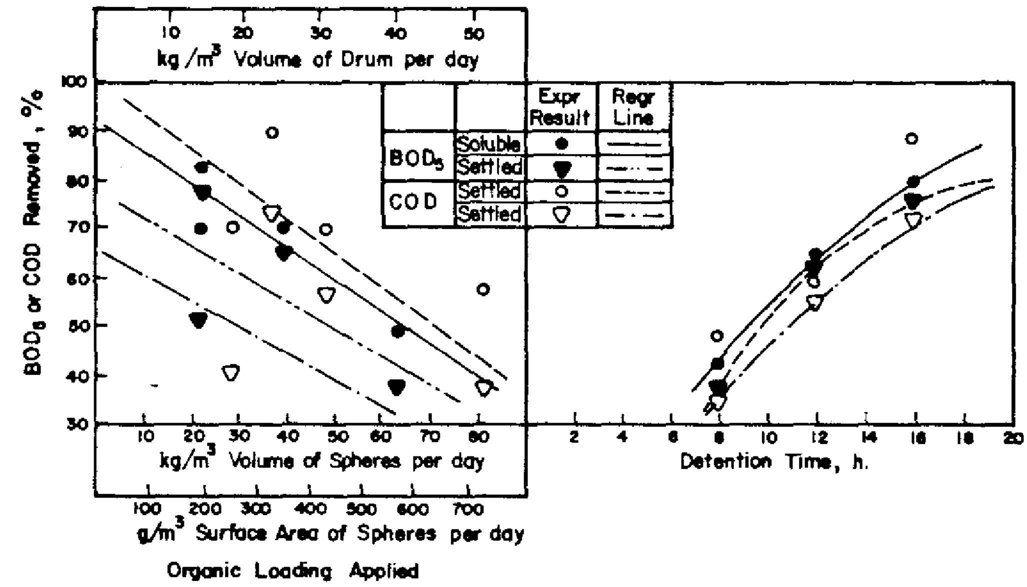

Fig. 3.4 Effects of Organic Loading and Detention on Organic Removal in Rotating Biological Drum Filtration of Combined Tapioca Starch Wastewater

Waste Treatment and Production of Yeast

Protein shortages have given rise to an increasing interest in production of single-cell protein from organic wastes. Thanh and Wu (1975) reported on use of Torula yeast to treat tapioca starch separator waste from a 1st grade factory. It was found that Torula yeast could acclimatize and grow predominantly in the waste, reducing sugars and volatile acids being readily removed. Overall COD reduction was about 73 per cent and the yeast mass contained approximately 50 per cent protein with a yield of 0.5 kg yeast per kg COD removed. However, nitrogen supplementation was necessary at a level of 1 kg nitrogen per 50 kg COD removed. When the yeast was grown in non-enriched waste, the protein content of the yeast decreased significantly. The effluent from yeast treatment of the waste still contained a relatively high residual COD and would require further treatment before discharge. Additional waste treatment after yeast growth would complicate an already sophisticated process and both factors militate against this form of waste handling being suitable for tapioca starch factories.

C. General Remarks on Tapioca Starch Wastewater Treatment Studies

Wastewaters from the tapioca starch industry are highly polluting and constitute a major source of surface water pollution in regions where the crop is processed. Work carried out in Thailand has identified the characteristics of the principal wastewater streams from 1st and 2nd grade tapioca starch factories and given an insight into feasible treatment processes.

It is apparent that, under normal conditions, washwater from both grades of factory should not be mixed with the other wastes discharged. Sedimentation alone, to remove gross solids, will ordinarily be a satisfactory form of treatment for this waste. At times when the organic content of the settled washwater is high, chemical treatment before sedimentation would often produce a satisfactory effluent but, if this is not effective, then the settled washwater should be treated with the other wastes as a combined flow.

There is a range of alternatives for treating the separator wastewater from 1st grade plants or the sedimentation tank supernatant from 2nd grade plants, which are very similar in nature. Because of their very high BOD_5 and COD concentrations, these wastes are amenable to anaerobic biological treatment and anaerobic ponds are an effective first-stage treatment process. Following treatment in either a single pond or multiple stages of anaerobic ponds in series, the effluent will require further aerobic biological treatment before discharge. The choice of aerobic process will depend principally upon the cost and availability of land near the factory. A detailed economic analysis of treatment alternatives for tapioca starch wastewater is given by Luken (1976). In general, where land is available and cheap, facultative ponds will be the cheapest form of aerobic process and probably two stages of ponds would be necessary. Where land is more costly or scarce, aerated lagoons should be adopted for treatment of effluent from the anaerobic ponds. Rotating biological filtration is also a high-rate aerobic process suitable for treating either the effluent from anaerobic ponds or the settled raw tapioca starch waste and should be considered when land utilization must be minimized. It is possible with all these forms of treatment to include primary sedimentation but this would normally only be economic when anaerobic ponds are used if the settled solids can be sold as animal feed. If a rotating biological filter or other aerobic process were to be adopted as sole biological treatment, sedimentation would be necessary as a first stage.

Although it is possible to produce Torula yeast in treating tapioca starch waste, it is unlikely that this will be a feasible approach in the near future. Because of the lack of sophistication of processes and workers in the tapioca starch industry and low marginal profits it is advisable to think in terms of simple low-cost methods for waste treatment.

It seems that the anaerobic/aerobic treatment system provides a rational and effective means to treat this waste. However, at the present time, few factories have any control over their waste discharges and those that do attempt any form of treatment are guided by expediency alone and have usually limited their wastewater processing to inadequate holding in ponds.

3.2 Rubber Processing Industry

Natural rubber industry is Malaysia's largest foreign exchange earner as well as the main source of income and employment in the country. During the processing of rubber, water is used for washing, cleaning and dilution. It is estimated that about 80 million litres of effluent is discharged per day from Peninsular Malaysia alone into nearby streams and rivers (Ma, 1975). For a factory producing about 20 tonnes of dry rubber, it is estimated that about 410,000 litres of effluent are discharged every day. Studies on the treatment, disposal and utilization of effluents from rubber processing factories have been undertaken by the Rubber Research Institute of Malaysia (RRIM) with emphasis given to the effluent ponding treatment more than to effluent utilization. The effluent treatment program is considered successful to a certain extent.

In the natural rubber industry a variety of rubber/latex products are manufactured, of which about 14 per cent is the form of latex concentrate; the remaining 86 per cent is produced as dry rubber such as SMR block rubber, RSS and crepes of all types and grades. Quality and composition of effluent discharged from rubber/latex factories depend on the type of process employed. Fig. 3.5 shows various sources of effluent from latex concentrate processing by centrifugation.

a. Rubber/Latex Effluent Characteristics

A study was conducted by Muthurajah et al.(1973) on the physical, chemical and biological properties of effluents from typical rubber processing factories of SMR block rubber, RSS, remilled rubber and latex concentrate. A summary of the results is given in Table 3.5. It can be seen that effluent from latex concentrate is the most polluting with respect to chemical and biological properties since a substantial concentration of decomposable organic matter and ammoniacal nitrogen is discharged. Generally the composition of the waste consists of processed water, small amounts of uncoagulated latex and latex serum containing substantial quantities of proteins, sugars, lipids, carotenoids, inorganic and organic salts (John, 1972).

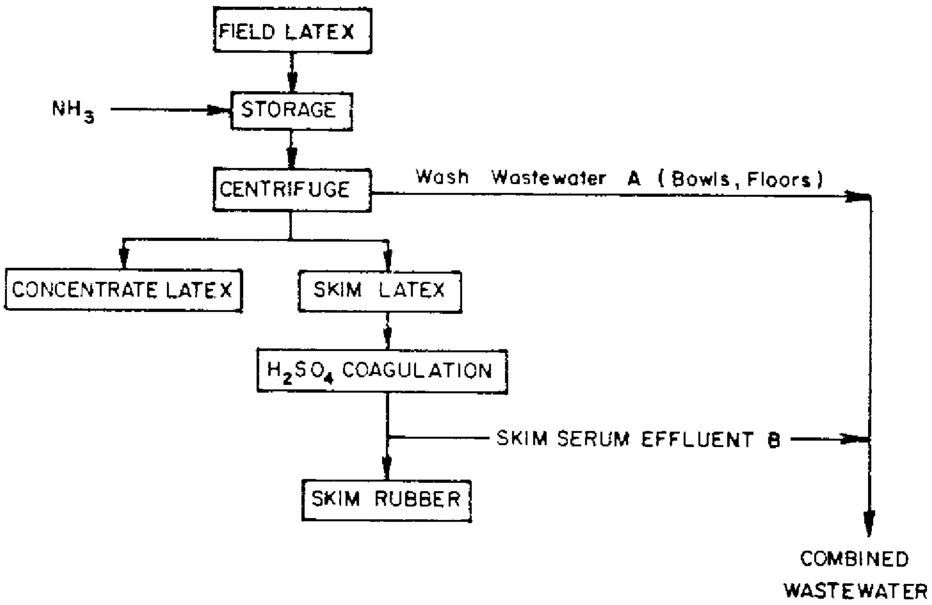

Fig. 3.5 Latex Concentrate Process

Table 3.5 Characteristics of Rubber Wastewaters
(Mutharajah et al., 1973)

Sample	pH	Settleable Solids	Suspended Solids	Total Solids	COD	BOD	$N-NH_3$	Org-N
Block rubber factory	6.3	155	230	995	1,620	1,140	55	20
RSS factory	4.9	50	140	3,745	3,300	2,630	10	100
Remilling fa factory	6.2	205	350	480	900	740	15	10
Concentrate factory	4.2	100	190	6,035	4,590	2,580	395	85

All values except pH expressed in mg/l

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From Table 3.5 it is also observed that effluents from the four types of factories are acidic as indicated by the pH values ranging from 4.2 to 6.3. The acidic nature of the effluents is attributed to the use of formic acid, phosphoric acid, or sulphuric acid in the process line. The effluents also contain fairly large amounts of total solids, suspended, dissolved and settleable solids. The BOD values for the concentrate, RSS, SMR block rubber and remilling factories are about 2,600, 2,600, 1,100 and 700 mg/l, respectively, while the corresponding COD values are 4,600, 3,300, 1,600 and 900 mg/l. The high BOD and COD values of the latex concentrate and RSS wastewaters indicate the total solids are mainly of organic origin and readily degradable. Average ratio of BOD to COD in rubber wastewater is about 0.69 indicating that the waste is biologically degradable. As in the case of tapioca starch wastewater, it is likely that high BOD and COD indicate that anaerobic biological processes will be effective.

Total nitrogen includes ammoniacal nitrogen combined with organic (mainly albuminoid) nitrogen. In the four types of effluent, it is noted that the main contribution to total nitrogen is ammoniacal nitrogen. This is due to the use of substantial quantities of ammonia in the preservation of latex. The amount of ammoniacal nitrogen is highest in effluent from latex concentrate factories. Ammonia is toxic to fishes and should not be discharged into receiving waters. Large amounts of ammoniacal nitrogen discharged to rivers or streams are undesirable because it promotes algal blooms due to conversion of ammonia into nitrates. Such waterways are unsuitable as water supply sources. In addition to this, presence of ammonia in domestic water supply requires the addition of large amounts of chlorine as ammonia has a high chlorine demand, and reacts with chlorine to form a series of chloramines.

b. Rubber/Latex Effluent Treatment

Considering the characteristics of rubber effluent, biological treatment consisting of an anaerobic pond followed by a stabilisation pond appears suitable as it requires minimum equipment, maintenance services and skilled supervision, and tropical climatic conditions assist a great deal in improving the system efficiency, if land availability is not a constraint.

Block Rubber Waste Treatment

As in the case of tapioca starch waste treatment, anaerobic ponds are the simplest and cheapest anaerobic form of treatment for block rubber and concentrate latex wastewaters but will not achieve an effluent quality suitable for discharge to waterways and a final aerobic stage of treatment will be necessary.

Ahmad Bin Ibrahim et al. (1974) conducted series of tests with an anaerobic pond (9.57 x 4.88 x 2.74 m) followed by a stabilisation pond (10.97 x 5.49 x 1.24 m), as shown in Fig. 3.6. Ranges of organic loadings varied from 125-445 kg BOD/1,000 m^3-day in the aerobic pond, and 11-86 kg BOD/1,000 m^3-day in the stabilisation pond, with corresponding detention times of 5-13 days in both ponds. The effect of organic loading on BOD removal is shown in Fig. 3.7 and Fig. 3.8 for the anaerobic pond and the stabilisation pond, respectively. In both cases, the BOD removal efficiency drops with increased organic loading, but the BOD removed across the anaerobic and aerobic ponds increases with increased organic loading. No fouling occurred in the anaerobic pond even at 445 kg BOD/ 1,000 m^3-day. However, when BOD loadings were increased beyond 63 kg

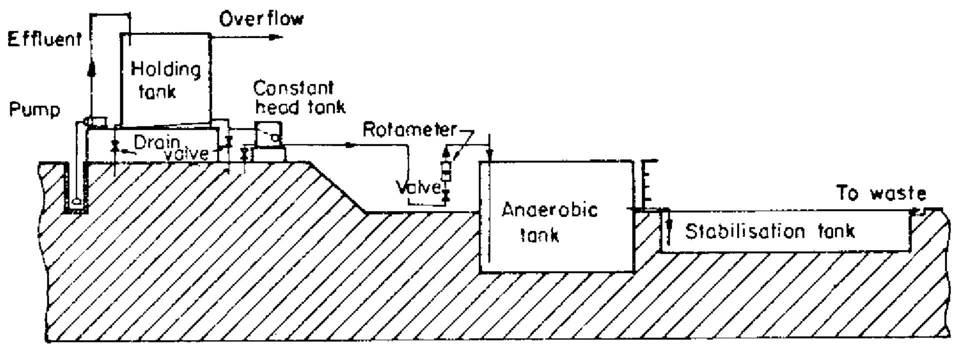

Fig. 3.6 Schematic Flow Diagram of Experimental Plant (not to scale) (After Mutharajah, 1973)

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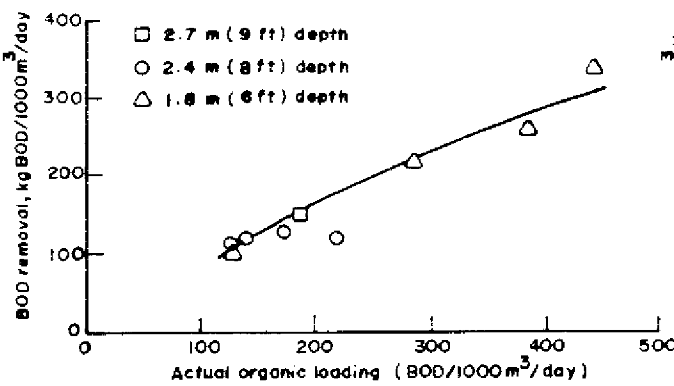

Figure 3.7 Effect of organic loading on weight of BOD removal, anaerobic treatment

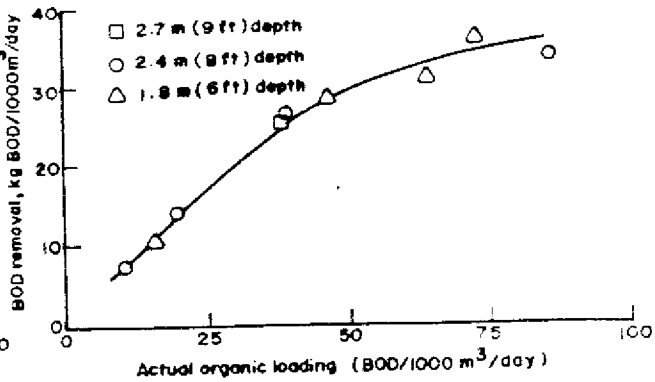

Figure 3.8 Effect of organic loading on weight of BOD removal, aerobic treatment

BOD/1,000 m^3-day, fouling occurred resulting in destruction of algae, evolution of malodorous gases and reduction in the removal of ammoniacal nitrogen.

Based on the results obtained, it can be said that, if the initial BOD level is around 1,500 mg/l, a retention period of about 10 days is required to produce an effluent with a BOD concentration suitable for further treatment by a stabilisation pond where the detention time could be about 12 days. The recommended organic loadings for the anaerobic and stabilisation ponds are 150 kg BOD/1,000 m^3-day and 40 kg BOD/1,000 m^3-day, respectively. It has been demonstrated that an anaerobic stabilisation pond, when operating under optimal conditions, is capable of treating block rubber wastewater, removing approximately 95% BOD, 85% COD, 70% volatile solids, 40% ammoniacal nitrogen and 50% total nitrogen.

Latex Concentrate Waste Treatment

Ponniah et al. (1975) also applied anaerobic — aerobic system to treat the latex concentrate wastewater, as shown in Fig. 3.9. It consists of a 27 m^3 concrete pond, an overnight steel retention tank and a 27 m^3 "earth bund" aerobic pond. The flow rate was regulated in such a way to provide retention periods of 30 days in each pond. Results of

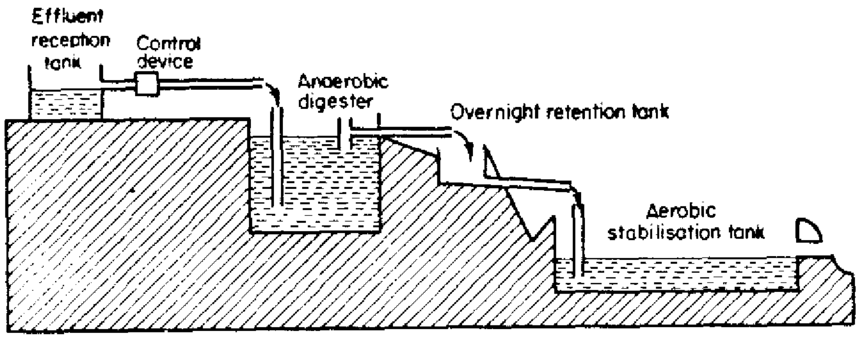

Fig. 3.9 Plan of pilot plant for treatment of acidified latex concentrate effluent.
(After Ponnial etal. ,1975)

the study are shown in Table 3.6. It can be seen that the BOD level of the effluent is brought down to 100 mg/l after removal of algae by centrifugation. The final concentrations of ammoniacal nitrogen (250 mg/l) and total nitrogen (310 mg/l) are still high compared with those obtained from block rubber effluents. It is peremptory that nitrogen levels be

Table 3.6 Results of Pilot-Plant Scale Treatment of Acidified Latex Concentrate Factory Effluent. (After Ponniah *et al.*, 1975)

Test	Anaerobic Digestion			Aerobic Oxidation			Reduction Combined Treatment (%)
	Before Treatment	After Treatment	Reduction %	Before Treatment	After Treatment	Reduction %	
pH	6.2	7.4	-19	7.3	8.0	-10	29
COD	7,920	4,560	58	4,780	800	83	90
BOD[a]	5,840	3,080	47	3,250	100	97	98
Ammoniacal nitrogen	1,230	870	29	900	250	72	80
Total nitrogen	1,330	910	32	950	310	67	77

All units are in mg/l except for pH.

[a]Analyses conducted after removal of algae by centrifugation.

brought down to as low as a level as possible in the final effluent prior to discharge for irrigation purpose. A high nitrogen content in irrigation water is alleged to affect the yield of paddy plants. Agriculture authorities recommend that irrigation water for paddy schemes should have less than 10 mg/l of total nitrogen and 5 mg/l of ammoniacal nitrogen. A high nitrogen content in water supply in terms of nitrites and nitrates is undesirable and unsuitable for human consumption. The properties of latex concentrate wastewater are much different from those of block rubber waste particularly in ammoniacal nitrogen (500 mg/l) and sulfate (1,500 mg/l), concentrations. The high sulfate level is due to excessive usage of spent sulphuric acid in the coagulation of skim latex. In an attempt to reduce levels of ammoniacal nitrogen and sulfate in the treated effluent, an anaerobic/three-stage facultative ponding system was used to treat latex concentrate wastewater (Ponniah et al., 1976). The rate of removal of ammoniacal nitrogen was generally poor, and the presence of hydrogen sulphide gas was detected in all ponds. It is well known that high ammoniacal nitrogen and sulphate levels can have adverse effect on bacterial viability and function. A more systematic approach is necessary in order to solve this important problem.

c. General Comments on Rubber Wastewater Treatment Studies

The anaerobic - aerobic ponding system seems to be the solution for the treatment of block rubber waste, but has encountered limited success for the treatment of latex concentrate waste, due to high concentrations of ammoniacal nitrogen and sulphate in raw latex wastewater. The application of artificial aeration of the anaerobic effluent has been successful in some rubber factories in Malaysia with regard to the removal ammoniacal nitrogen and sulphate. It is recommended that more other aerobic biological systems be approached to treat the anaerobically treatment effluent, and study on ammoniacal nitrogen removal be deeply studied.

3.3 Palm Oil Waste Treatment Study

Oil palm is an increasingly important crop in Malaysia and recently also in Thailand. In areas where oil palm is grown and processed, palm oil wastes contribute considerably to stream pollution. The process to extract oil from fresh fruit bunches (FFB) required large quantities of water, mainly for sterilizing the fresh fruit bunches and oil clarification, and large amounts of wastewaters are released. The total quantity of effluent waste produced in 1975 was estimated at over 3 million tonnes. Assuming that the waste has an average BOD concentration of 20,000 mg/1, thus the total load of BOD discharge into watercourses was estimated at approximately 210 tonnes per day. With crude palm oil production in 1980 being expected to double 1975 estimate, the potential quantity of BOD that is expected to be generated by the oil palm industry will be nearly 450 tonnes per day. In terms of population equivalent, the BOD generate by the oil palm industry in 1980 will be equivalent to that generated by a human population of approximately 10 million persons.

Heavy pollution of land and streams by these wastes has forced the authorities concerned to adopt stringent measures against reckless discharge of these wastes without any treatment. The Division of Environment, Ministry of Science and Technology of Malaysia has been issueing a programme involving a progressive reduction of pollution from the oil palm industry over a 4 year period, envisaging a 75% reduction in the pollution load by 1st July 1978, 90% by 1st July 1979, 95% by 1st July 1980 and 97.5% by 1st July 1981. That means that BOD concentration must be reduced from a level of 20,000 mg/1 to 5,000 mg/1 by the first year of enforcement. The required levels are 2,000 mg/1, 1,000 mg/1 and 500 mg/1 consecutively for the subsequent years. Wastewater for land disposal is generally required to be treated to a BOD level of 5,000 mg/1 prior to disposal.

This move has generated the recent creation of the Palm Oil Research Institute of Malaysia (PORIM) vesting similar structural organisation as the Rubber Research Institute of Malaysia (RRIM). Thanks to the International Development Research Center (IDRC) according a research grant to AIT's Environmental Engineering Division, an extensive systematic study on palm oil waste treatment is being conducted in cooperation with the Division of Environment, Ministry of Science and Technology, and the

Federal Land Development Authority of Malaysia. Encouraging results have been obtained, and it is hoped that they could be useful for PORIM to launch its future investigations. (Thanh et al ., 1979)

Palm oil, a fruit-coat oil, is a semi-solid, edible oil extracted from the pulpy portion (mesocarp) of the fruit wall of the oil palm (Elaeis quineensis). The oil palm originated in the Guinea coast of West Africa and is now Malaysia's second most important crop, next to rubber and is recently becoming attractive in Thailand.

Palm Oil is extracted from fruit bunches by a semi-continuous process. Fig. 3.10 shows a general process flow diagram of a palm oil mill. The freshly cut fruit bunches, delivered to the mill daily, are first loaded in cages mounted on railway and run directly into a horizontal sterilizer where live steam is used to heat the fruits to about 140°C at a pressure of 2.5-3.2 kg/cm^2 (35-45 psi) for 50-75 min. The purpose of sterilization is to de-activate the enzymes responsible for the breakdown of oil into free fatty acids and to loosen fruits from the stalks. Thereafter, sterilized bunches are fed into a rotary-drum threshing or stripping machine which separates the fruits from the bunches. The empty bunches drop into a conveyer belt that carries them to an incinerator and burn into ash, whereas the loose fruits are converted into a homogeneous oily mash by a series of rotating arms (digester). The digested mash is then fed into a press for extraction of crude oil. Nuts must not be broken at this stage of the process. The solid matters of nuts and pressed fibre are then separated to recover the nuts which are subsequently dried and cracked to produce kernels for sale. The pressed fibre and some of the shells are usually burnt as fuel in the steam-raising boiler.

The extract crude oil consisting of a mixture of oil, water and some fine solid material, is passed through a vibrating screen to remove solids present. Hot water is often added in this operation. A clarification tank is used to separate the oil by gravitation and the oily sludge settles at the bottom. The clarified oil is further purified in a vacuum dryer prior to pumping into a storage tank. The oily sludge, after straining and desanding, is centrifuged to recover the oil which is returned to the clarifier and the sludge is discharged into an oil trap, where further oil is recovered by heating the sludge with steam prior to the discharge of the sludge to a stream.

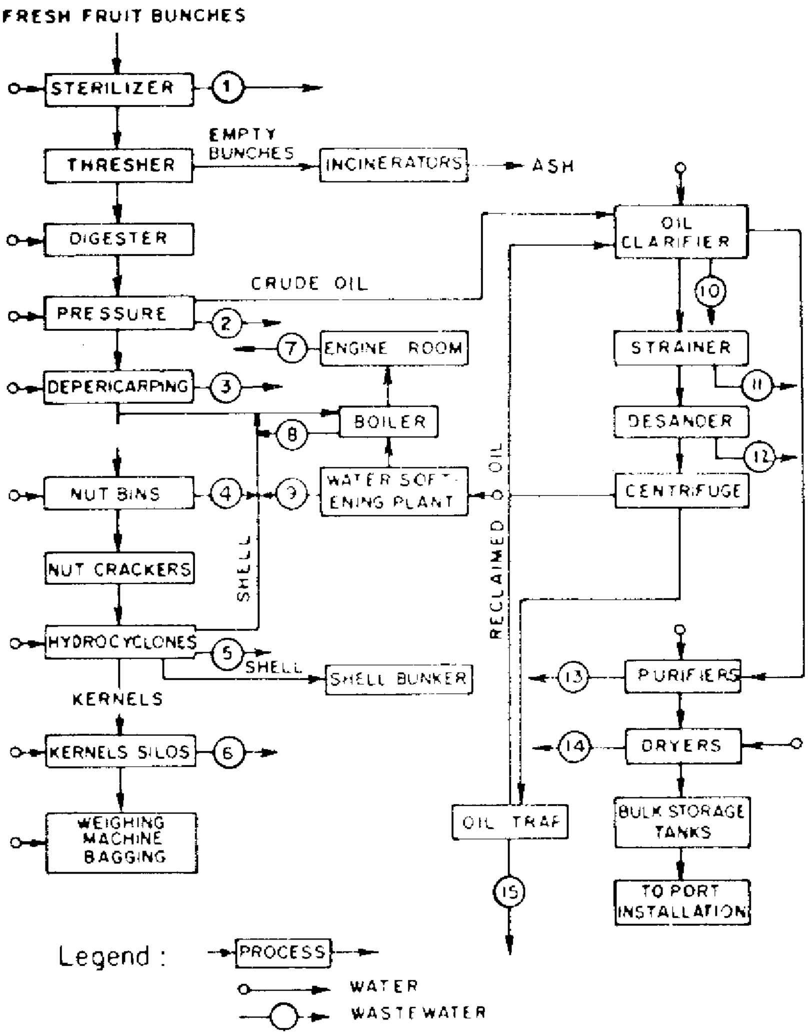

Fig. 3.10 General Process and Wastewater Flow Diagram of a Plan Oil Mill

(1) Sterilizer's condensate, cleansing of sterilizers and floor washing

(2) Floor washing

(3) Steam condensate

(4) Steam condensate

(5) Hydrocyclone discharge

(6) Steam condensate

(7) Turbine cooling water and steam condensate

(8) Boiler blowdown

(9) Overflow and backwash water of the water softening plant

(10) Floor washing of the oil room

(11)
(12) Wastewaters discharged from various units in the oil room
(13)

(14) Overflow from the vacuum dryers

(15) Oil trap discharge

a. Palm Oil Wastewater Characteristics

The combined wastewater from palm oil extraction is mainly composed of two kinds of wastes, the sterilizer condensate and the clarification sludge. In addition to these two principal wastes, discharges occur from other sources, such as claybath separators or hydrocyclones, floor drains, boiler blowdown, condensing water and discharge from steam traps. Large mills in Malaysia process in the order of 960 tonnes FFB per day (about 60 tonnes/h) while average factories commonly process about 320 tonnes FFB per day (20 tonnes/h).

The characteristics of palm oil wastewaters have been reported by several investigators as summarized in Table 3.7. It can be seen that palm oil contains a large amount of suspended solids, and very high concentrations of total COD and BOD_5. The combined waste is acidic in nature, its pH being about 4.5, resulting from the release of free fatty acid during the extraction process. Palm oil wastewaters are highly organic but have relatively low nitrogen and phosphorus concentrations. The organic nature of palm oil wastewaters indicates that the waste is biologically degradable. It is likely that biological methods will be most economical for this type of organic waste and the high BOD_5 and COD concentrations suggest that anerobic biological processes will be effective. The temperature of wastewater samples was found to range from 80 to 90°C, which needs to be brought down close to 40°C to make amenable to biological waste treatment processes.

Recent investigation by Thanh et al. (1979) has shown that combined

Table 3.7 Characteristics of Palm Oil Wastewaters

Characteristics, mg/l (except as indicated)	Sterilizer Condensate		Clarification Sludge		Combined Wastewater			
	Ma (1975)	Thanh (1977)	Ma (1975)	Thanh (1977)	Ma (1975)	Singh & Ng (1968)	Aziz (1974)	Thanh (1977)
BOD_5	18,000		20,000		18,000-20,000	19,800	14,000-16,000	
COD	55,000	59,700	60,000	87,760	40,000-58,000		29,000-46,000	57,120
Suspended Solids	51,000	10,600	35,000	11,000	30,000	15,420	4,800-5,400	33,500
Dissolved Solids	25,000		25,000		25,000	23,500	16,000-27,000	
Oil	0.7		0.7		0.7	.57		
pH	4.5	4.75	4.5	3.7	4.5	4.8	4.4-4.5	4.8
NH_3-N	-		-		30	25	39	27
NO_3-N	-		-		9.3	41	9.3-10.4	
Org-N	-		-		576	522		
Total-N		700		756				644
Phosphorus		150		150	200			277
Temperature, ^{o}C					80-90			
Volatile Acids		2820		3990				1950
Alkalinity		1400		nil				500

waste discharged amounted to 2.9 m^3/tonne FFB at 50 percentile and 3.5 m^3/tonne FFB at 90 percentile. Table 3.8 summarises the contribution to pollution by different parameters. Table 3.9 gives fifty per-

Table 3.8 Pollution Loads in Terms of Per Tonne of FFB

Wastewater Parameters, mg/l	Pollution Load, kg/tonne FFB			
	Mill A	Mill B	Mill C	Overall Mean
BOD_3^*	33.30	29.50	31.23	31.34
COD	66.06	63.03	68.67	65.92
Total-N	0.63	0.71	0.81	0.72
Total-P	0.42	0.42	0.40	0.41
Oil & Grease	25.21	25.68	11.35	20.75
Total Solids	52.95	54.78	49.67	52.47
Suspended Solids	23.56	25.33	27.63	25.50

*BOD_3 : 3 days incubation at 30°C adopted in Malaysia

centile values of the combined wastewater characteristics at 3 palm oil mills under investigation. Generally, the combined wastewater is acidic in nature, pH varying between 4 to 6.8. Oil and grease content is very high, which indicates that proper measures should be taken for oil and grease removal prior to treatment total solids and suspended solids concentrations are substantially high, inviting that sedimentation is possible. The BOD_3:COD ratio, indicative of the biodegradability of the waste, is expected to be high. However, it varies between 0.46 and 0.55. This ratio must be carefully interpreted in this case, as many aromatic and cellulosic substances could not degraded during the BOD_3 determination. Notwithstanding this discrepancy, highly organic nature of palm oil waste indicates that this waste is amenable to biological treatment. Again, there is reason to believe that anaerobic/aerobic biological system is a viable combination for the treatment of palm oil waste.

b. Treatability of Palm Oil Waste

Treatability studies were carried out in Malaysia and in Thailand (Thanh et al., 1979). In Malaysia, tests were conducted by two anaerobic ponds in series without any initial adjustment of pH in the waste. Details of study are summarised in Fig. 3.11. It was observed that two-stage anaerobic pond of 30 days detention time substantially reduces COD_F content in the waste, readily to be subsequently treated by completely mixed activated sludge process. The final effluent denoted a reasonable content of COD_F and BOD_3 so the waste could be discharged into receiving streams without any adverse effect.

Table 3.9 Fifty Percentile Values of the Combined Wastewater Characteristics

Palm Oil Mill	COD	BOD_3	BOD_3/ COD	TS	SS	Total-P	Total-N	Oil & Grease	pH
A	28,500 mg/l	14,000 mg/l	0.49	23,000 mg/l	10,000 mg/l	163 mg/l	265 mg/l	9,600 mg/l	4.0-5.7
B	18,300 mg/l	10,000 mg/l	0.55	15,500 mg/l	7,500 mg/l	135 mg/l	230 mg/l	8,200 mg/l	4.2-6.8
C	31,500 mg/l	14,500 mg/l	0.46	22,700 mg/l	12,500 mg/l	180 mg/l	366 mg/l	5,300 mg/l	-

In Thailand, palm oil waste was treated by two anaerobic ponds in series with initial adjustment of pH by lime (Fig. 3.12). Detention time was 15 days in one pond, and 20 days in the other. It was observed that the characteristics of the effluents from two ponds were similar, with a very high reduction in COD_F and BOD_5. Subsequent treatment by extended aeration activated sludge process revealed that the effluent BOD_5 was brought down to about 50 mg/l, which is considered to be quite an achievement of this treatability study scheme.

c. Remark on Palm Oil Treatability Study

Anaerobic - aerobic treatment system revealed to be an immediate solution to the handling of palm oil waste prior to discharge into receiving streams. At the moment of this report writing, works continue to be carried out by applying a wide spectrum of aerobic biological systems to treat the effluent from anaerobic pond, e.g. oxidation ditch, trickling

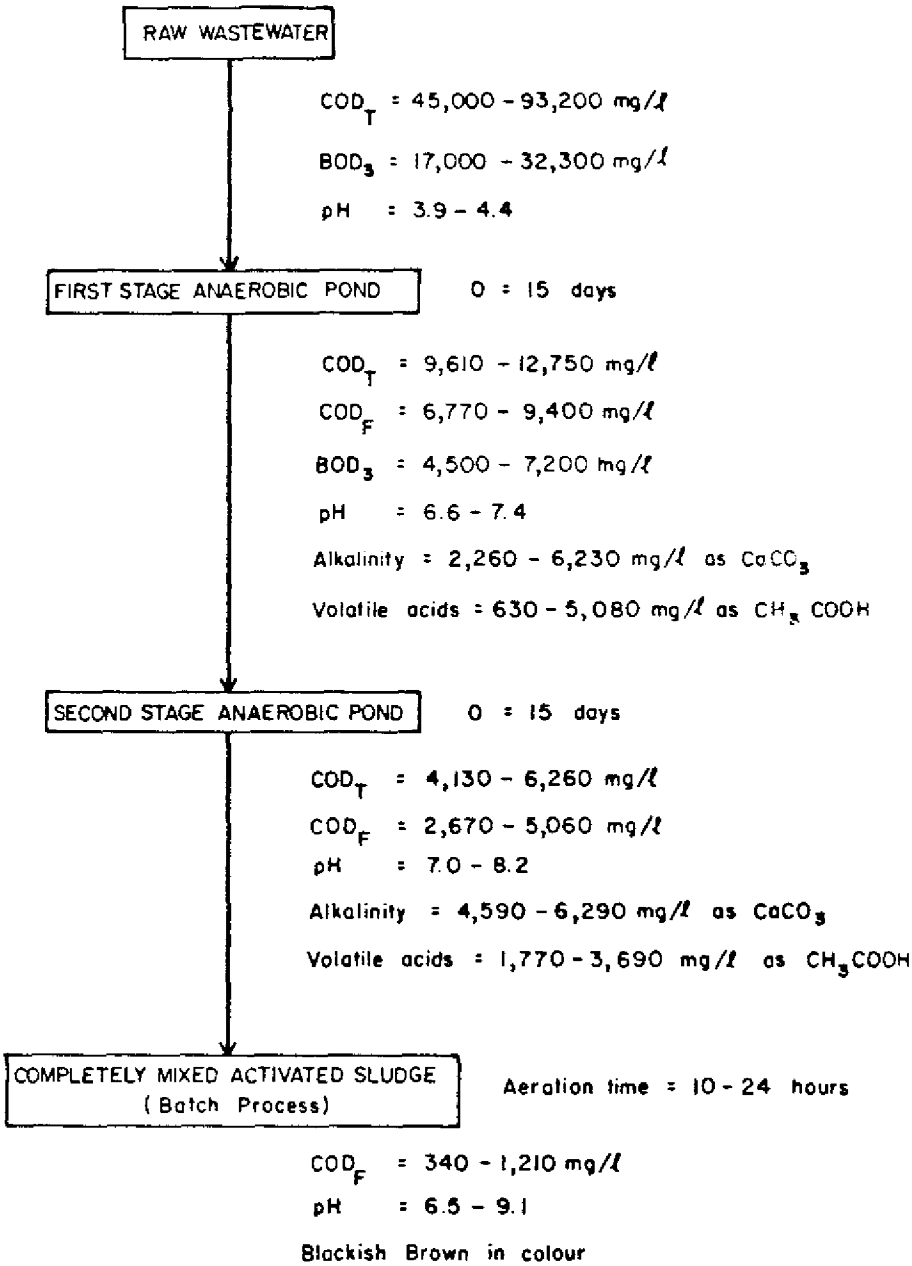

Fig. 3.11 Treatability Study Scheme in Malaysia

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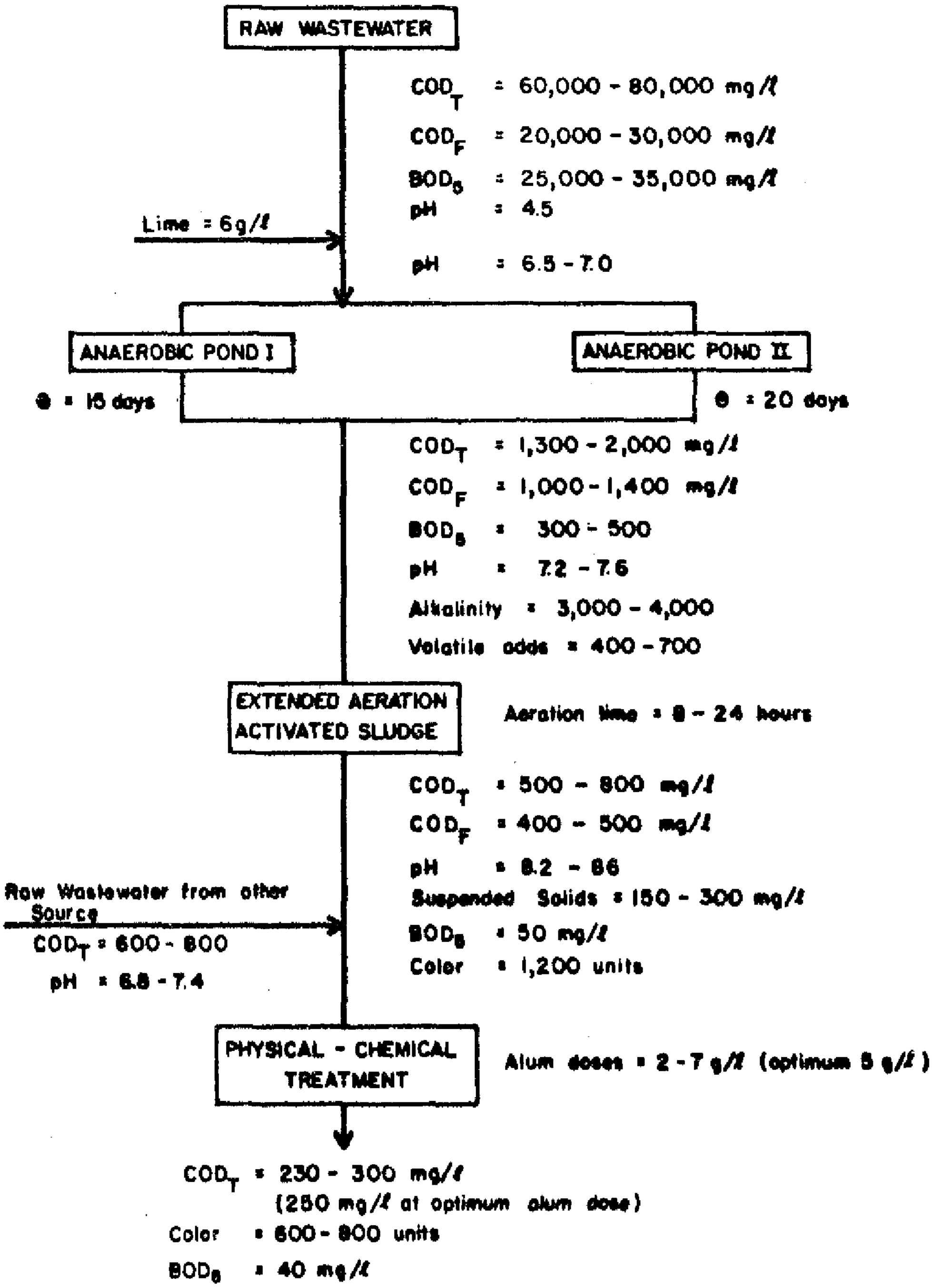

Fig. 3.12 Treatability Study Scheme in Thailand

filter, bio-drum, oxidation pond, facultative pond, aerated lagoon. Results will be published at a later stage.

This form of study could constitute an investigation prototype for other industries, encompassing in-plant evaluation, flow measurement, wastewater sampling and analysis, laboratory treatability studies. Recommendations on water conservation and process modifications were also brought about in an effort to achieve a better water management. It is noticed that palm oil mills, in general, are facing water shortage during dry spell period, conservation of water whenever possible should be practised. For example, proper handling of water taps and hoses in the premises must be applied, recirculating the turbine cooling water, overflow from vacuum dryers and steam condensates from boiler house, is desirable; fruits dropped into drains should be manually collected instead of being flushed away with tap water. Oil and grease in waste must be separated prior to treatment. It is always expensive to treat a wastewater once it is generated; reduction of wastewater discharge should be tackled at its source by modifying or eliminating unnecessary activities without affecting the quality of final product.

It is to hope that pilot study could be conducted upon the completion of laboratory treatability studies, based on the existing local conditions of the factories and relevant economic treatment systems.

3.4 Sugar Cane Wastewater Treatment

The wastes produced in the cane sugar manufacturing process vary according to local conditions, plan site, water availability. Generally, the wastes may be divided into: condenser water, cane washwater, floor washing consisting of spillage and leakage, and boiler blowdown (Fig. 3.13).

The condenser water has a degree of pollution caused by improperly controlled evaporators. A considerable quantity of sugar may be carried into the condensate resulting either from an excessive foaming condition or from lack of control of evaporator levels.

Canes harvested must be washed because of the soil and other organic matter adhering to the canes water utilised for cane washing usually has

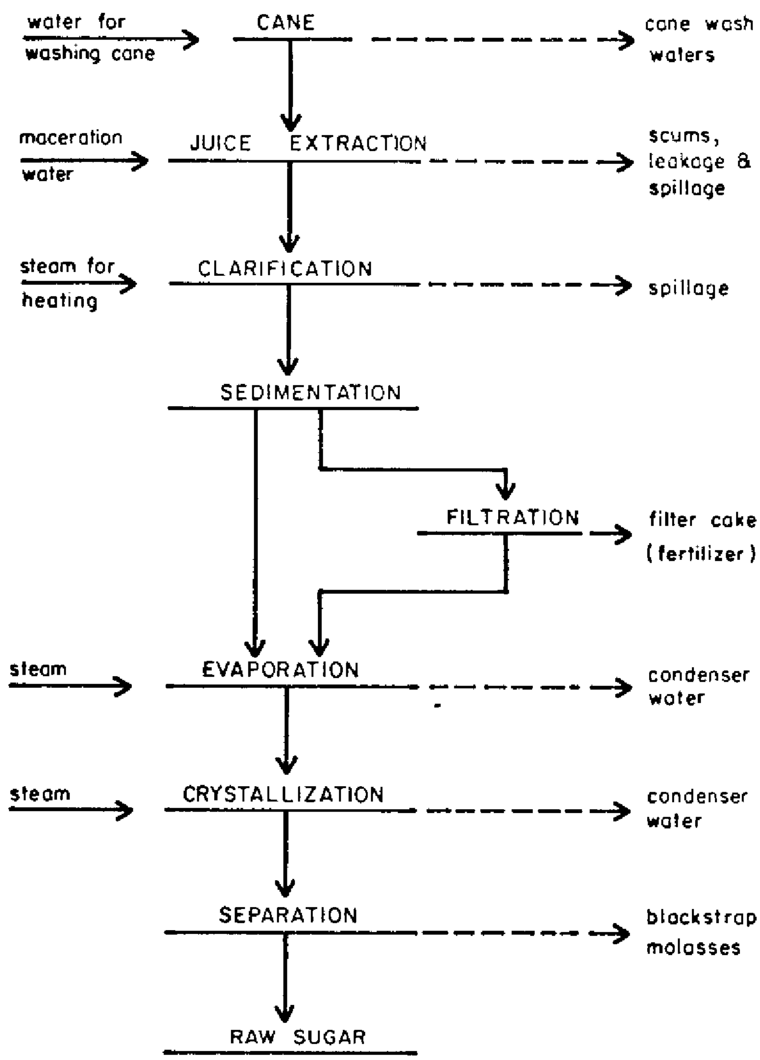

Fig. 3.13 Diagrammatic Flow Sheet of the Process of Raw Cane Sugar Manufacture

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previously been used as cooling water. Cane washwater generally has high BOD.

The pollutional effects of floor washings are largely caused by sugar spillings and careless or improper operations. Boiler blowdowns, less in volume than condenser water, also have a pollutional effect.

Table 3.10 summarises the characteristics of sugar cane wastewater from the Cholburi sugar factory in Thailand. Treatment of this waste by stabilisation pond has been reported quite successful (Liares, 1966). With a loading of 5.6 g BOD/m^2-day and 15 day detention time, the effluent filtered BOD is reduced to 19 mg/l.

An example of successful case of sugar cane wastewater treatment in relation to water quality management was reported by Vicharangsan (1979). The Maeklong River Basin (about 100 km west of Bangkok) is a cane growing area with an annual cane output of 9 million tonnes. During cane - crushing season, a dozen sugar mills used up about 2.5 million cubic metres of water a day as coolant and cleanser and discharged 150-200 tonnes of organic pollutants per day, equivalent to a population of 3-4 million people. The temperature of the wastewater entering the river of 45 to 50°C contributed to complete destruction of the river system and led to nation-wide complaints.

The Department of Industrial Works of Thailand requested the offending millers to take corrective actions or have their licenses revoked. Various corrective measures were tried to curb the pollution problems of this river basin without much success. Finally, in early 1974, the Department of Industrial Works and the sugar millers agreed not to discharge effluent into the river. They were to jointly build and operate a central wastewater treatment plant to serve the 13 sugar mills which formerly had discharged effluents into the river. The mills would buy land and share construction costs, whereas the Department of Industrial Works would operate the plant; annual expenses of which would be charged to individual mills, based on tonnage of cane crushed, pro rata.

Table 3.10 Characteristics of the Sugar Cane Waste from the Cholburi Sugar Factory (Source: Liares, 1966)

Determination	Grab Sample*	6-h Composite Sample**
Flow, m^3/s	0.317	0.317
Flow, mgd	0.73	0.73
BOD_5, mg/l	352	423
Total daily BOD, lb	2150	2570
Total daily BOD, kg	976.00	1160
BOD, lb/ton product	16.7	19.8
BOD, kg/1,000 kg product	7.4	9.0
COD, mg/l	841	960
NH_3-N, mg/l	0.30	0.19
NO_2-N, mg/l	0.03	0.04
NO_3-N, mg/l	8.1	9.5
Organic-N, mg/l	1.20	1.20
Total N, mg/l	9.63	8.89
Phosphorus (as PO_4), mg/l	0.40	0.17
Total solid, mg/l	554	916
Total volatile solids, mg/l	280	555
Suspended solids, mg/l	72.0	176.0
Volatile SS, mg/l	46	44
Settleable solids, ml/l	0.1	0.1
Alkalinity, mg/l	18.8	22
D.O., mg/l	5.0	6.0
Temperature, °C	46	46
pH	5.8	6.1

*Average of four samples

**Average of three samples

A budget of US 1.0 million was set aside from the government's sugar price stabilisation fund, to be repaid at an interest rate over a time period. A farm land of 40 ha was purchased at US$150,000, and pond construction began. Construction costs amounted to US$850,000. Treatment equipment and facilities has cost some US$200,000 so far.

In addition, the sugar mills had to install pretreatment facilities at their sites in a view to recycling cooling water and to alleviating the burden of the central plant. Officers of the Department of Industrial Works were dispatched to control the pretreatment operation at the mills, and to operate the central plant itself. According to the report, (Vicharangsan, 1979) the Maeklong River Basin System has been restored to a manageable lifeline. Treated effluent containing some useful elements as soil nutrients serves as supplementary irrigation to the surrounding canefields. Virtually, all water is now distributed to the cultivation of cane in that area.

Costwise, it is reported that this central treatment plant has been successful economically. Expenses for four years of operation and some 30 million tonnes of cane crushed (2.55 million tonnes of sugar produced) have amounted to about US$0.5 million including depreciations, at the cost of US$0.017 per tonne of cane or US$0.20 per tonne of sugar to protect the environment.

General Remarks

Sugar cane wastewater is easier to treat than tapioca, rubber and palm oil wastes. Cooling and condenser wastewaters are high in volume and low in BOD. They should be reused as much as possible to minimise stream pollution. Fig. 3.14 is a flow diagramme of a sugar mill designed to minimise water pollution as well as to provide maximum reuse as suggested by Stone (1951). Concentrated wastes from spillage, scum leaks, and grease and oil from machinery are low in volume and high in BOD. Stabilisation pond has been proved to be a successful treatment system to treat sugar cane wastewater, at a reasonable cost.

9461

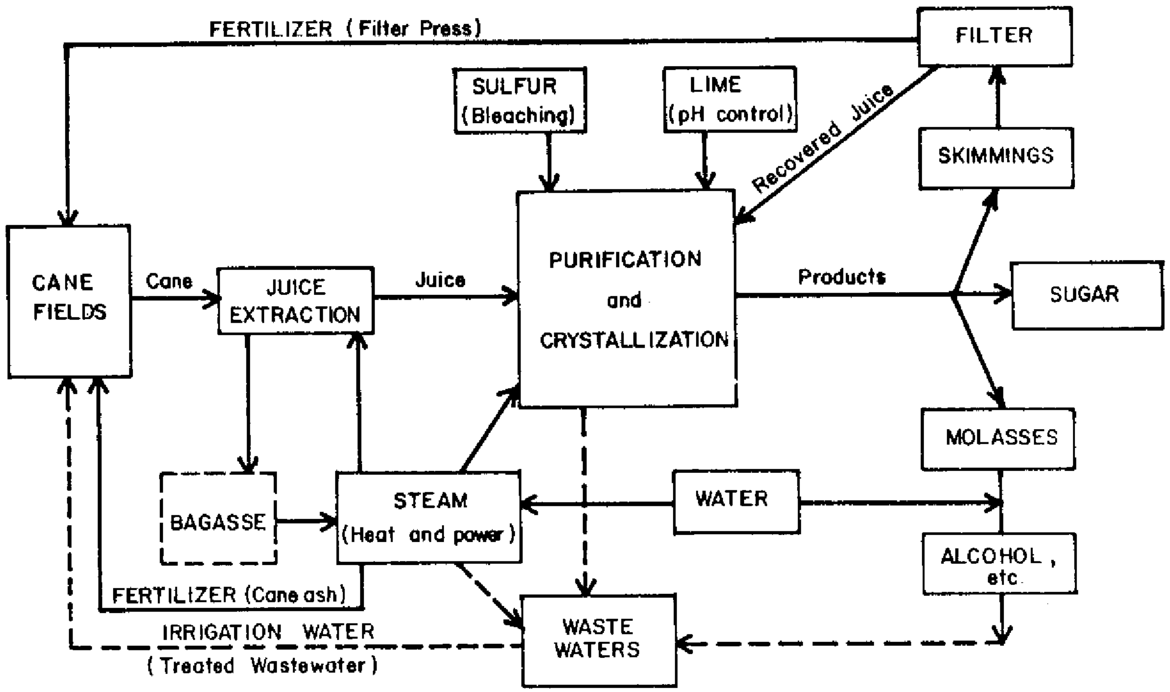

Fig.3.14 Flow Diagram of Sugar Mill Operation Showing Utilization of By-Products and Wastewater to Minimize Water Pollution

9481

3.5 Coconut Processing Wastewater

The coconut industry plays a vital role in the economy of the Philippines, ranking the first as coconut supplier in the world, providing 80 per cent of its total production to international trade in the form of copra, coconut oil, desiccated coconut and copra meal. In Malaysia, the coconut ranks as third largest crop in terms of acreage, covering about half a million acres, and producing about 90,000 tonnes of coconut oil (Ma, 1975).

Fig. 3.15 shows the pattern of desiccated coconut manufacture and its sources of wastewater. The copra industry produces a large volume of coconut water usually released as wastewater, at the rate of 136 litres per thousand nuts. Based on the estimate of 227 kg of copra per 1,000 nuts the volume of coconut water produced in 1970 in Malaysia is estimated at 11 million litres (Ma, 1975), released to the environment without any treatment. A desiccated coconut plant which splits about 300,000 coconuts per day throws out approximately 90,000 litres of pure coconut water (based on 0.3 litre coco water per nut) plus about 750,000 litres of wash water (based on 2.5 litres of wash water per nut).

Table 3.11 gives analyses of effluents from two desiccated coconut plants and standard Class C. It can be seen that the characteristics of desiccated coconut wastewater change from plant to plant. Wastewaters are highly organic but have relatively low nitrogen and phosphorus concentrations. Ratio of BOD_5 to COD of 0.8 indicates that this waste is biologically degradable. In terms of BOD_5, COD and suspended solids, desiccater coconut wastewater is very similar to tapioca starch wastewater. It is then logical to advance that anaerobic biological treatment would be an effective first-stage treatment process, followed by aerobic biological treatment before discharge.

Efforts have been made to treat desiccated coconut wastewater directly by conventional activated sludge, as illustrated in Fig. 3.16. It can be seen that treatment of wastewater for expediency purpose is not an appropriate approach if reasonable effluent is to be achieved.

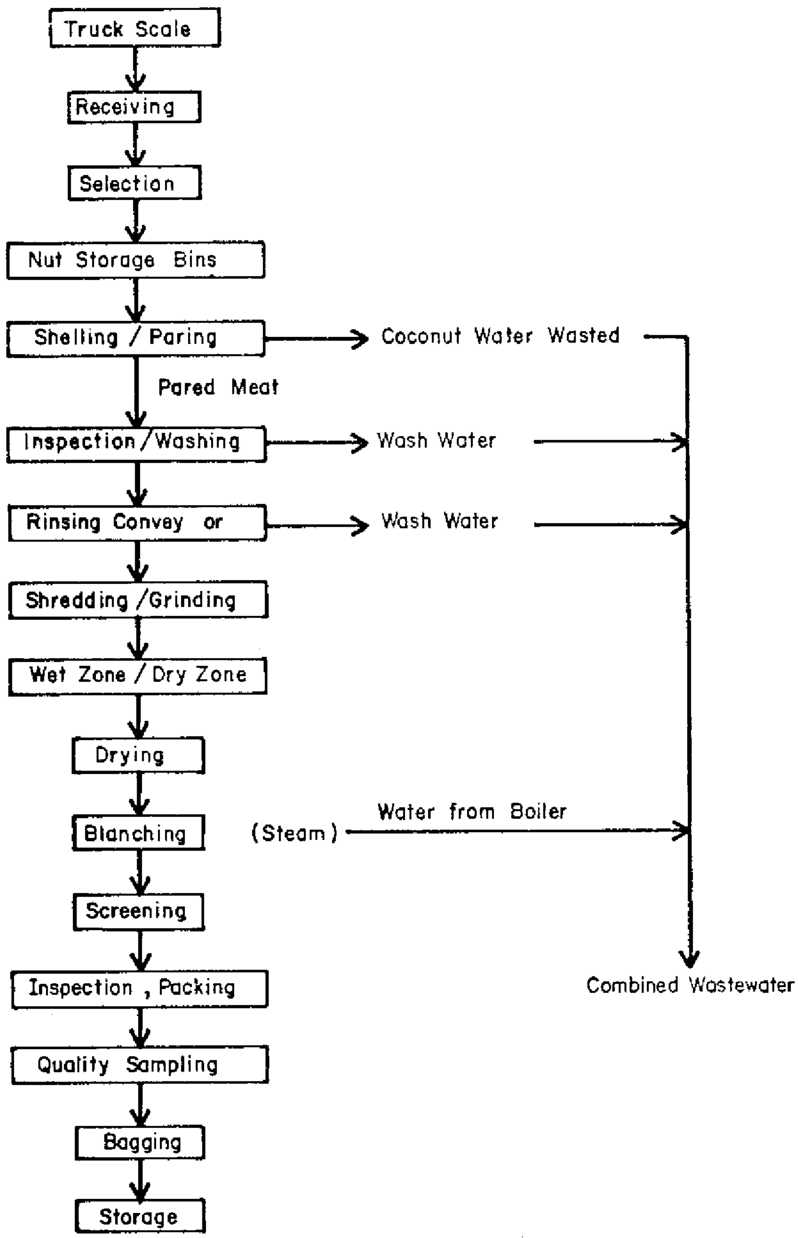

Fig. 3.15 Desiccated Coconut Manufacture and Sources of Wastewater

Table 3.11 Typical Analysis of Effluent from Desiccated Coconut Plant and Standard Class C

Parameters mg/1, except as indicated	Plant A	Plant B	Standard Class C Waters
pH	6.3	4.7	6.5-8.5
Acidity	759	-	
BOD_5	5,800	14,000	20
COD	-	17,000	
Phosphate	43	-	
$N\text{-}NO_2$	0.12	-	
Phenols	4.8	-	0.02
Suspended Solids	184	2,600	
Volatile Susp. Sol.	180	-	
Settleable Solids	-	90	
Dissolved Solids	-	9,400	1,000
Total Solids	-	12,000	2,000
Grease & Oil	76	-	5
Temperature, °C	36	-	
DO		0	5

Recommendations

The following recommendations could be made with regard to treatment of desiccated coconut wastewater:

1. Coconut water is rich in nutrients and contains important growth factors which are an excellent growth medium for fermentation. Ideally, the most economic and practical approach is to make use of the coconut water as growth medium in fermentation to derive some products from it and then treat the effluent in conformity with pollution control standards. But economic aspects of recycling are questionable; the volume is too large to be processed economically: The treatment of coconut water to reduce its BOD remains the direct approach to the pollution problem.

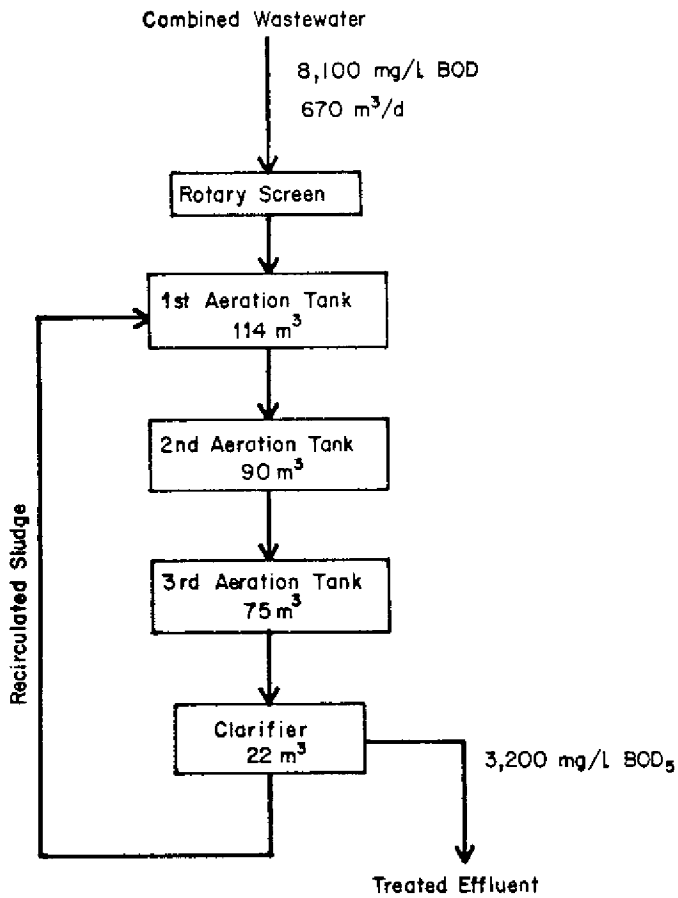

Fig. 3.16 Scheme of Treatment of Desiccated Coconut Wastewater in One Typical Plant

2. The investment in wastewater treatment is dependent on the volume of waste to be treated and the quantity of polluting material discharged. Hence, it is worth attempting to minimize water use and investigating major sources of polluting materials rather than just accepting the waste streams as discharged. An in-plant evaluation of water use and waste generation is necessary to achieve these objectives.

3. It is necessary to instal flow measurement devices on the major wastewater streams to be able to determine the magnitude of waste discharges and their variability. Fluctuation in flow, the minimum and maximum flows will be monitored to cover the full operating period of the day and determine diurnal and weekly variability.

4. The variability of flow is supplemented by changes in wastewaters characteristics in the various streams. It is important that wastewater streams are sampled for analysis at the same locations where measurement is being made.

Grab samples will be taken from each waste stream in proportion to the flow every hour throughout a 24-hour operating period and these individual samples will be composited for detailed analysis. This operation will extend over many days for each waste stream until the wastewater quality variability can be assessed. Next, samples from each wastewater stream will be collected for analysis on an hourly basis to determine diurnal variation and wastewater quality.

5. Individual wastewater streams and/or combinations of the separate streams will be subjected to appropriate treatment as indicated by the wastewater analysis. Recommendations will be made on the most suitable sequence of treatment units processes and on their likely efficiencies, taking into account space availability. This will provide basic data for treatment plant design.

IV APPROACHES TO WATER POLLUTION CONTROL

4.1 Alternatives in Water Pollution Abatement

Water pollution control is only one aspect of water resources management. A rational approach to the control of water pollution should view the available technological measures as aids to efficient resource utilization, that is, to maximize the overall economic and social returns. The priorities assigned to various water uses are political decisions which define the constraints to be applied in managing water quality in a region. However, the necessary quality demands of legitimate water uses and alternative quality management schemes must be evaluated technologically.

Fig. 4.1 shows the cycle of water use by society wherein water and other materials are inputs to industrial processes (including agriculture) or to a city, and wastewater is the one output with which we are concerned. There are obviously many points in this cycle at which an attempt could be made not only to minimize the quantity of polluting materials being discharged but also to reduce the effects of the discharged pollutants. The consideration should also include the capacity of a water body to accept waste discharges without seriously affecting subsequent uses of the water. Management alternatives available for improving the quality of receiving waters are summarized in Table 4.1. Some of the more important of these alternatives are discussed in greater detail in the following sections.

4.2 Minimizing Wastewater Generation

In developing countries and in those which have lax pollution regulations, the potential for reducing wastes generation from industrial plants is great. Few present-day plants have been designed or are operated with any consideration of wastes, and misuse of water is widespread.

The quantity and quality of wastes released by industry are functions of raw materials used, the nature and operation of the production

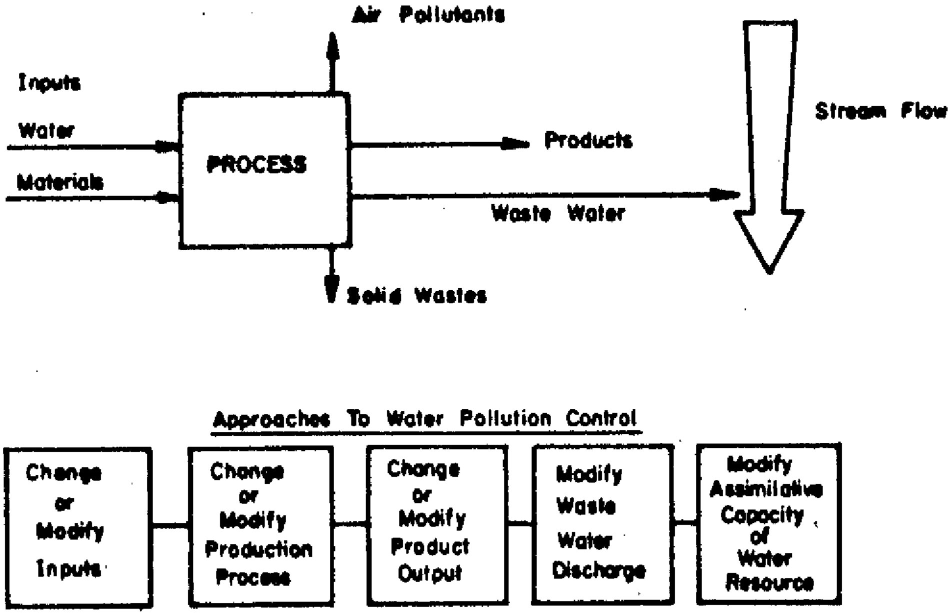

Fig. 4.1 Cycle of Water Use and Approaches to Pollution Control

Table 4.1 Technological Alternatives in Water Pollution Abatement (Source: Kneese and Bower, 1968)

Principle	Method
A. Reducing Wastes Generation	1. Change type of raw material inputs 2. Change or modify production process 3. Change or modify product outputs 4. In-plant recirculation of water 5. Segregation of concentrated waste streams 6. Waste elimination
B. Reducing Wastes after Generation	1. Materials recovery 2. By-product production 3. Waste treatment 4. Effluent re-use
C. Increasing or Making Better Use of Assimilative Capacity of Receiving Water	1. Addition of dilution water 2. Multiple outlets from reservoirs 3. Reservoir mixing 4. Reaeration of streams 5. Saltwater barriers 6. Effluent redistribution

process, the final products produced and water usage. There is a wide range of variations not only among wastes from different industries but also among wastes from different plants within an industry. Thus, even if the general constituents of an industry's waste are known, each plant's discharge will raise its own peculiar problems and be amenable to particular solutions based on individual study. The aim of this approach to pollution abatement should be to reduce the volume and strength of wastewater generated per unit of raw material processed or final product manufactured.

Sometimes a change of raw material input or product output can have significant effects on wastewaters released from a plant. Wastes from agricultural product processing and fruit canning are highly dependent, from the point of view of quality, on the growth, harvesting and transport of the raw product. Changes in consumer demand over time have stimulated the development of new products which have implications in wastes generated.

Although most changes in production process have been brought about for reasons other than water pollution abatement, process changes often have the major impact on wastes generation. Usually there are several ways of producing a given product so that there are possibilities for modifying almost all processes to reduce wastes released. As acceptance of the external costs of wastes released to the environment is forced on industry, the generation and control of wastes will be considerations in process design and will be accounted for in production costs.

Another effective way of reducing waste generation in an individual plant is to concentrate on improving its operation. If the particular process is operated at maximum efficiency the conversion of raw material to product should be high, resulting in less losses in waste streams. Organizing plant maintenance to minimize leaks of water and materials and general good housekeeping in a plant can often reduce the waste problem significantly, particularly after the major sources of waste materials have been identified. One other possibility to reduce the quantity of waste for subsequent treatment is segregation of strong wastes, which might allow the bulk of relatively unpolluted wastewater to be discharged without treatment.

In-plant recirculation of water is also an effective method of reducing wastes generation. Small plants can often effect a significant waste volume reduction through changing to a recycled cooling water system from a once-through system. Large plants, such as thermal power stations, will normally already be using recycled cooling water because of the large water volumes required for cooling. Many other process wastewaters, particularly if not heavily polluted, can be recycled for reuse in parts of the process with less exacting water quality requirements. Processes converting agricultural crops, such as the production of tapioca starch, use large quantities of water and if limits are placed by authorities on water use, water recycling will be encouraged. Future increased water demands will result in a greater need for water conservation, and recycling and reuse by industry of both its own and municipal wastewaters will become more common.

4.3 Resource Conservation and Recycling

Water is an important resource which can be conserved and recycled both by industry and municipalities. However, there are other materials contained in municipal and industrial wastes which can and should be reduced. Materials recovery and by-product production are two methods for reducing wastes after generation which differ by reason of the product being reused within or outside of the same production unit, respectively.

Another alternative is to process a waste for the purpose of producing a by-product to be used as an input to other production processes or for consumption. One example for direct use, without processing, of a waste stream is that of molasses, from sugar cane processing, which is used by distilleries. Industrial and municipal wastes have also been used in recent years for the production of single cell protein (yeasts and algae) which can be used to offset serious protein shortages in the future. Sale of by-products not only helps to offset industrial production costs, an incentive to adopt this approach, but benefits society through reduction of the indirect costs of pollution discharges. An ideal system of waste handling would reclaim valuable materials and water for reuse, produce marketable by-products and effectively eliminate or limit water pollution - and do so at a cost which would provide a net profit to society. This panacea has not yet been found even for the handling of municipal wastewaters, which are much more consistent than industrial effluents.

4.4 Wastewater Storage and Diversion

If advantage has been taken of feasible methods of wastes reduction and still a significant amount of wastewater is to be discharged to a receiving water, effluent redistribution in space or time will often eliminate or minimize waste treatment. Storage and regulated discharge of wastes, transfer of wastes to a different location for discharge, and underground disposal are possible ways of achieving this. These methods have little or no effect on waste loads and do not modify the receiving water but are aimed at making better use of the assimilation capacity of water resources.

Storage of a waste before discharge will have the effect of equalizing quality so that sludge emissions of highly concentrated waste, such as occur on tank cleaning, can be diluted with the regular waste flow before discharge. This in itself will often prevent some of the more serious manifestations of gross pollution, such as fish kills. In tropical countries, the high evaporative losses from water surfaces might allow a wastewater problem to be converted into a solid waste problem, if wastewater discharges are only seasonal or of small volume and sufficient land is available for storage. Regulated discharge, in combination with temporary storage, takes advantage of the extra dilution afforded during periods of high flow. In an estuary or on the coast this may mean storage during the ebb tide and discharge on the flood tide. Seasonal storage during low flow periods may be adopted by certain types of industry but if daily wastewater discharges are high the storage volume required will be large.

Transfer of wastes from one location to another for discharge to take advantage of a greater assimilation capacity, is often practiced in areas near tidal estuaries or oceans. Transport of wastes or treatment plant effluents by submarine outfall to points where greater dilution is provided will often allow a lower degree of treatment to be provided than would otherwise be necessary. Sewage treatment plant effluents have often been used for irrigation purposes and this prevents direct discharge to receiving waters. Wherever water is short, farmers will be pleased to receive municipal plant effluents and industry will often pay for the privilege of using them.

Underground disposal of very concentrated wastes which are difficult or expensive to treat has been adopted by certain industries. Effluents are discharged into relatively deep formations containing little water or water of such poor quality as to be unsuitable for public use. This type of disposal represents a consumptive use of water and should not be adopted except for small quantities of waste. Reuse of treated municipal wastes is possible through recharge of underground aquifers with properly treated plant effluent. Recharge may be by injection wells or recharge grounds on the surface if an outcrop of the stratum exists. This has only been adopted where water is very scarce, because of possible health hazards and public aversion to sewage recycling, but it could well be necessary in areas where overpumping of aquifers is resulting in saline water intrusion and/or ground-surface sinking.

4.5 Modification of Assimilative Capacity

Flow augmentation through streamflow regulation is becoming increasingly adopted for water quality improvement throughout the world. Controlled releases from reservoir storage is effective in increasing the assimilative capacity of rivers and estuaries by providing increased dilution and oxygen supply. However, the effects of reservoir storage on quality of the stored water may militate against an improvement in quality downstream after release. While storage equalizes fluctuations in certain quality variables and improves others, important characteristics may be adversely affected. If a reservoir stratifies thermally, water in the lower layer (hypolimnion) can become devoid of dissolved oxygen and if subsequently released will not provide additional oxygen supply for downstream use. The unfavourable effects of storage can be overcome if they are anticipated. Multiple level draw-offs enable water to be released from the depth of best quality for the dilution purpose served. Stratification can be prevented or cured through reservoir mixing by inlet and outlet design, pumping, or use of compressed air.

The other major possibility for improving the oxygen supply available in a receiving water is actually to improve reaeration. This can be done using vacuum breakers to introduce air into water in the turbines if there is a power installation at a reservoir. Artificial weirs along a river are known to provide aeration but generally will not be capable of preventing adverse conditions arising. More violent aeration would be needed to be effective under heavy waste loading conditions and mobile or fixed aeration devices must be introduced. Mechanical aerators or diffused air systems would be provided in the region of the low point in the sag curve. There will obviously be an economic limit to the capacity which could reasonably be installed for this type of duty and the period over which it is necessary to operate will also be important.

A combination of methods may be desirable in a particular instance and it may often be necessary to coordinate a method or methods of improving the assimilation capacity of a water resource with waste control and treatment measures to arrive at a least cost solution. Individual abstractions or discharges of water from or to a receiving water for any purpose must not be allowed without considering their effects on the waste assimilation capacity.

4.6 Wastewater Treatment

Wastewater treatment has not been widely adopted in developing countries because the costs are significant and the direct benefits to a manufacturer or municipality have been considered zero or low. The industrialist generally has not considered the external damages and social costs caused by his waste discharges sufficient incentive to invest in waste treatment, but increasing pressure is being applied to industries to control their wastes. More developed countries of the region have had only limited success in controlling industrial wastewater discharges and environmental conditions in major cities are often worse than in cities in developing countries. However, much more investment is being made in wastes control and research directed towards improving the situation in those countries. The situation with regard to municipal wastewater treatment in many developing countries is complicated by the fact that conventional sewerage systems are not often found in cities. Without wastewater collection and transport to central plants, the cost advantages of large scale treatment plants cannot be achieved.

However, here again, it may be necessary to think unconventionally in arriving at a solution because the capital cost of installing sewers in large cities is usually prohibitive. From the point of view of water pollution control it is as important for municipal wastewaters to receive treatment as it is for industrial wastes. Furthermore, it is only fair for the authority forcing industry to control its wastes to do the same with the municipal sewage, which will be of greater pollutional capacity than industrial wastes in most developing countries at the present time.

When economic processes of materials recovery, by-product production and effluent reuse fail to prevent a residual waste load from an industry or community exceeding the assimilation capacity of a receiving water it is necessary to treat the waste before discharge. In designing and operating a waste treatment plant, full advantage should be taken of the receiving water's assimilative capacity, in its original or modified state. This may mean a phased development of plant as waste residuals increase and flexible design of units to allow varying degrees of treatment efficiency to match the stochastic nature of stream assimilation capacity.

The combination of unit processes making up a treatment plant flow diagram will depend on the characteristics of the particular waste and the effluent standards imposed. Invariably, the costs of constructing and operating a wastewater treatment plant increase with the degree of treatment required and so the controlling authority should be careful to impose only those stream standards essential for downstream water uses. Because of the economics of scale resulting from larger capacity plants, regional wastewater treatment plants should be considered where a number of industrial plants are located in one area. Table 4.1 shows a listing of unit processes commonly used for treatment of degradable organic materials. It can be seen that most processes have an output, which generally needs further handling, and so cannot be considered complete disposal devices.

The unit processes marked with an asterisk (*) in Table 4.1 are considered most suitable for use in tropical developing countries either by reason of their suitability for the prevailing climatic and labour

Table 4.1 Wastewater Treatment Unit Processes for Degradable Organic Materials.

Material to be Removed or Converted	Unit Process	Output from Unit Process
Degradable organic materials:	Aerobic Biological Treatment:	
	Activated Sludge	Sludge
	Biological Filters	"
	* Biological Disc Filters	"
	* Oxidation Ditches	"
	* Oxidation Ponds (Facultative)	Algae
	* Aerated Lagoons	"
	Anaerobic Biological Treatment:	
	* Anaerobic Digestion	Sludge
	* Anaerobic Contact	"
	* Anaerobic Lagoons	"
	Adsorption:	
	* Activated Carbon	-
Sludges:		
Inorganic and organic	Concentration:	
	* Clarifier thickening	Concentrate
	* Gravity thickening	"
	* Flotation	"
	Dewatering:	
	* Drying Beds	Dry-cake
	* Lagoons	"
	Filtration - gravity	"
	- vacuum	"
	- pressure	"
	Centrifugation	
Sludge:		
Organic	Digestion:	
	Aerobic	Sludge
	* Anaerobic	"
	Heat Drying and Combustion:	
	Heat drying	Dry-cake
	Incineration	Solid residue + gases
	Wet oxidation	Solid residue
Liquid effluents and solid residuals	Final disposal:	
	Land fill	
	Fertilizer	
	Stream Discharge	
	Sea Discharge	
	Irrigation	
	Underground Disposal	

conditions or because they utilize little or no imported equipment (or for both reasons). It should always be the aim to adopt methods which are particularly suited to and take advantage of prevailing environmental conditions. For example, the high temperature conditions in tropical countries promote the use of anaerobic biological treatment for organic wastes and the lack of skilled labour encourages the adoption of unsophisticated processes. It is normal to attempt to use the lowest cost solution to a waste treatment problem but this is especially important under the economic restrictions in developing countries. In addtion, particularly with industrial plants, the investment in waste treatment should be related to the financial conditions and tax structure of the country; the high interest rates usually found in developing countries will encourage low capital investment with higher operating costs, which is not uncommon with industry in developed countries. It is necessary, therefore, for the technologist to be flexible and innovative in developing waste treatment processes which ideally suit conditions in a particular country, and for the authorities to be more susceptible to unusual solutions to water pollution problems.

While large cities eventually will be forced to adopt capital intensive systems for waste treatment, smaller cities and industries, particularly in developing countries, must think in less conventional terms if anything in the way of pollution abatement is to be achieved. Land intensive systems, and particularly treatment processes utilizing limited equipment needing specialized manufacture, suggest themselves as logical methods. However, land is never cheap and land intensive treatment processes should still be designed and operated to obtain maximum efficiency from land use.

Oxidation ponds have long been used in Australia and New Zealand for municipal waste treatment, and the cities of Melbourne and Auckland have built up a wealth of experience in operating these systems. Environmental conditions in tropical countries are ideal for the biological processes which occur in these ponds. Essentially, organic matter is broken down by bacteria in the ponds as in conventional biological treatment processes, aerobically in upper layers and anaerobically on the bottom. The oxygen requirements of the bacteria in facultative ponds are provided mainly by algal photosynthesis, while algae proliferate as a result of the carbon dioxide released by bacterial respiration. Ponds can be very cheap to construct, being formed by earth embarkments and not requiring lining if built on relatively impervious soil. One major advantage of oxidation ponds is their ease of operation and maintenance costs are very low.

Ambient temperature has a significant effect on pond performance and on the maximum organic loadings which they can tolerate. Facultative ponds in tropical regions can be loaded up to about(450 kg BOD per hectare day) without lowering BOD removal per unit of area, while anaerobic ponds or lagoons have been operated up to 51,660 kg BOD per hectare day (46,000 lb BOD per acre day) with high efficiency (McGarry and Pescod, 1970). Anaerobic systems are particularly suited to tropical conditions and anaerobic ponds are the cheapest possible form of anaerobic treatment. They are most effective on concentrated organic wastes, and tapioca starch wastes are typical of those agricultural product processing wastes amenable to treatment by this method. A final polishing of anaerobic pond effluent is necessary before discharge and this can be accomplished in facultative ponds. The cost of treatment using oxidation ponds depends on both the efficiency of land use (which depends on climate) and on the cost of land (which depends on location).

Oxidation ponds are an extremely flexible system of waste treatment. If originally designed as a number of facultative ponds in series, the first pond or ponds can be allowed to go anaerobic as loading increases and no further land is required. If the loading further increases, later ponds in the series system can be aerated using floating surface aerators to increase their treatment capacity and yet maintain aerobic conditions. If eventually an urban area has grown to the point where land value is too high to justify excess use for waste treatment, the land occupied by oxidation ponds is a reclaimable asset which can offset the costs of providing alternative secondary treatment.

An alternative process to oxidation ponds which has been used for small communities and industry is the oxidation ditch (Baars, 1962). In fact, this process is an extended aeration activated sludge process designed for a retention period of about 24 hours rather than the conventional activated sludge detention time of 6 hours. Land use is much less than for oxidation ponds which are usually designed for a minimum detention time of 10 days for treatment of sewage, to allow a greater die-off pathogens. The process has great appeal in developing countries because construction is simple and the only equipment necessary for a basic plant is an aeration rotor, which can be made locally. Operation is simple, maintenance cost is low and efficiency of BOD removal is high. Ditch construction can be cheap but is more costly than for oxidation ponds. Oxidation ditch treatment would not normally be adopted for large waste flows because of the high retention time in the plant. Cost of treatment using this method will generally be of the order of a regular secondary treatment plant because of the size.

There are capital intensive systems available for sludge handling and treatment but, at the present time in developing countries, land intensive methods will be more appropriate. Again, proper design will ensure maximum efficiency of land use and minimum cost. Available methods include evaporative lagooning and sand drying beds and most effective use of land will result from these methods being adopted in conjunction with sludge thickening and anaerobic sludge digestion to provide a more concentrated and less obnoxious material for dewatering (Pescod, 1971).

V CONCLUSIONS AND RECOMMENDATIONS

Developing countries are at an advantage at present in that they can learn from the mistakes of more developed countries and prepare for the inevitable environmental quality degradations brought about by urbanization. Engineers, planners, and administrators must have an awareness of the dangers of uncontrolled urbanization and be prepared to introduce measures to conserve a suitable urban environment. Following are some approaches which are necessary for control of pollution of the environment in developing countries.

Need for Base Line Studies

Development projects will always have an impact on the environment and developing countries must be prepared to invest in control measures which are designed to preserve potential natural resources and, at the same time, not to sacrifice for the sake of development. It must be realized that there is a delicate balance between economic development and environment control within which each country must work out itself. The reckless mismanagement of the natural resources without paying any heed into the consequent upset in the balance of nature can lead to ecological disasters. The objective of environmental control does not mean that development activities should be curtailed. However, it is desirable that impact assessment, both short-term and long-term, of the development. activities be made and management strategies be drawn for obtaining the least impact.

Developing countries are normally at a great disadvantage when it comes to evaluating the impact of projects because so little environmental data are extant, even for those parameters which are easily measured. For example, most developing countries in Asia have only short-term meteorological and hydrological data and often the monitoring of important variables, such as streamflow in major rivers, is intermittent and haphazard.

Before environmental impact of a development project can be assessed there is a need for background data on the physical, chemical and biological characteristics of the ecosystem. The environmental base line or back-ground study is designed to provide these data for impact evaluation and use in project design (particularly for pollution control measures), but is also useful in the monitoring of environmental quality changes after a project is implemented. It is advisable for Governments to sponsor baseline studies in connection with private developments so that the extent of any subsequent deterioration of environmental quality can be quantified. Sometimes private companies investing large sums in industrial projects that are known to be environmentally suspect may finance base line studies of their own as protection against any unjustified claims that they have denigrated the environment. One other important use of a base line study is in establishing the assimilative capacity of a natural system, consequently minimizing investment in control of polluting residual discharges. Base line studies are extensive and costly and must be carefully planned and executed. They do provide opportunity for training of local personnel in a developing country if handled by local organizations. Usually studies are cheaper when carried out by educational institutions rather than by private companies. It is essential that independent organizations with experience in environmental matters be employed to produce reliable impartial results.

Need for Environmental Impact Assessment

Before any large industrial or governmental development project is given final planning permission, a detailed environmental impact assessment should be prepared and considered. The purpose of an environmental impact analysis is to apply systematic techniques to measure the benefit and damages to the environment and see which species are affected adversely or beneficially. It may be considered to be in two parts: the evaluation and screening of projects which affect the environment to determine any adverse ecological reactions; and special studies of ecological impacts to ascertain the degree of biological damage and how it may be mitigated.

Applications for permit to construct development projects should include an environmental impact statement or report which discusses:

(1) the environmental impact of the proposed action,

(2) any adverse environmental effects which cannot be avoided should the proposal be implemented,

(3) alternations to the proposed action,

(4) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and

(5) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

Need for Environmental Reconnaissance

An environmental or ecological reconnaissance may be carried out to give a preliminary assessment of environmental impact of a project and to indicate those aspects which deserve further in-depth study. It provides only a cursory review of principal impacts and is therefore of more limited scope and depth than an environmental impact study. The time scale for environmental reconnaissance would be much shorter than for environmental impact, perhaps of the order of 1 to 4 or 1 to 5.

Even though a reconnaissance is expected to be less thorough than an impact study it should be as detailed and quantitative as time and resources permit. It will normally involve a multi-disciplinary team coordinated by a project leader, who might well be a environmental engineer. The outcome of the study should be identification of those environmental impacts of a project which need further study, recommendations on alternatives for those components of a project which are likely to be environmentally unacceptable, recommendations on actions which should be taken so as to preserve or exploit natural or cultural resources and reduce adverse impacts, and preliminary recommendations on the likely acceptability of the total project or alternatives (wherever appropriate) from an environmental point of view.

Normally, as a result of an ecological reconnaissance survey there will not be sufficient data on which to base a trade-off analysis and recommendations will normally be based on subjective evaluation of information available. Where a project is estimated to have little adverse impact on the environment, the ecological reconnaissance study may obviate the necessity for a full environmental impact study and thus reduce costs while still allowing further study and remedial actions to be carried out on specific aspects with adverse effects.

Standard Setting

Most of the developing countries do not have a set of standards for managing and maintaining a certain quality of the environment suitable for the various species including man to live in the ecosystem. Where standards are available, it is often found that those standards are not rational and are normally based on the standards developed elsewhere. Minimum environmental quality standards based on the maximum assimilative capacity of the environment should be the basis for drawing control strategies in the region. It is costly to maintain a level of environmental quality higher than the level required for safe living and for other beneficial uses. Therefore, the standards borrowed from elsewhere might not be suitable to the local conditions emphasizing the need for setting rational standards for the conditions and situations of a country.

Environmental Legislation and Punitive Control

Legislation and institution are necessary to administer and implement the policies and of environmental management. To introduce and improve the environmental legislation in the region, it may be worthwhile to review the present existing legislations in other countries, and make a thorough study to find out the success or the failure of legislative control so as to develop a rational approach for environmental legislation.

Punitive control although not an efficient approach for environmental quality management is a necessary means by which an environmental quality management agency can enforce its directives if necessary. In some instances, it could also provide a recourse for damaged parties who feel that their interests have not been appropriately taken into account by a management agency. Legal policies should be framed to incur damage cost but litigation should be used as the last resort for environmental quality management.

Economic policy approach may be quite effective in this region. Incentives in the form of effluent charges, payments, tax benefits, etc. may be introduced within the economic policies of the country encouraging the polluters to prevent environmental deterioration. For this purpose, the government should be vested with more powerful levers: economic leverages, economics of scale, and the energy of participation. Example: taxing leaded gas more than non-leaded; a price to be charged for air, and higher prices for water; taxation of urban land. Under economics of scale falls the concept of new towns. Those who plan for the human environment should be spending major shares of their time mobilizing and releasing the energies of the public through a variety of devices ranging from education to direct citizen control.

Environmental Organization

Environmental quality is something that should be considered at national policy making level. Better environmental quality management could be achieved by creating a unified organization to handle different aspects of environment, e.g. air pollution, noise pollution, water pollution, solid wastes, industrial wastewater etc. The organization should be empowered to impose standards, set targets standards for implementation and enforce regulations. Most often, the alternatives taken by a separate organization will not decrease the total level of pollutants, but merely transfer it to another state, transferring the problem to another organization.

The environmental policies should enhance and not adversely affect the present or future development potential of countries or hamper the attainment of better living conditions for all and appropriate steps should be taken by environmental organization at any level with a view to reaching agreement on the possible economic consequences resulting from the application of environmental measure.

Environmental problems have a unique global dimension, for they afflict every nation, irrespective of its political institutions, economic systems or state of development. It is important to develop more effective environmental efforts through appropriate environmental organizations in the region.

Regional and International Interrelation

The need for international collaborations arises from the fact that pollution and other environmental problems respect no political boundaries. Activities in a country can affect the neighbouring nations. For example, when rivers flow through many nations, it is in the interest of each affected nation that it does not render the waterways harmful for the country down-stream of the river for its utilization. A good illustration is the Mekong River which flows through Thailand, Laos, Cambodia and Vietnam.

Neighbouring countries can share a common sea or estuaries and any incidents or projects, which can take place in these waters may have environmental repercussions affecting the countries concerned. Thus, arrangements, treaties and collaborative decision makings between nations to handle these problems is a necessity. Coordination would also be required for the introduction of pollution control regulations on such as regional and international level.

Information Exchange and Surveillance

Permanent mutual information exchange will reduce costs in management programmes as a result of avoidance of repetitions in control methods, determination and setting of sets of standards if similarities in geographical, social and economic conditions are obvious. Regional and international surveillance can be achieved through regional and international organizations with their national counterpart organizations. These organizations should provide informations and guidelines for individual countries to manage their environmental problems.

Need for Environmental Education Development

The concept of environmental education involves consideration of the environment as a totality of natural and social systems in which human beings and other organisms live and from which they draw sustenance. Major environmental problems, in turn, will be analyzed according to the scale of the geographical areas affected (local, national, regional or global), the kind of biophysical and social concerns which arise and the different types of problems that different patterns and rythms of development pose. The solution of environmental problems in the context of development, it might be suggested, lies not so much in the field of technology, though technical skills are often essential, as in coping with the social, economic and cultural factors giving rise to them.

Environmental education is a part of the entire educational process and not to be regarded as a separate subject, simply to be added to educational curricula. The achievement of environmental quality goals demands an educational process which emphasizes the development of environmental awareness at the individual and collective levels; knowledge and skills; and socially sound values and behaviour. The target audience of environmental education would compose of all members and social categories of a community at all age levels, inside and outside the formal school system.

A function and methodological distinction may be made among three types of environmental education and training: (1) the general environmental education of people from childhood through adulthood in both the formal and the non-formal education sectors: (2) the environmental education of specific professional and social groups whose actions have an influence on the environment (engineers, architects, sociologists, economists, workers, industrialists, etc.); and (3) the training of scientists, technologist and other professional who deal directly with environmental problems (foresters, biologists, hydrologists, ecologists, and the like).

The characteristics of environmental education which are involved in the successful achievement of its stated goals and objectives include; a problem-solving approach; an inter- and multidisciplinary methodology; and a community-based orientation - all in a continuous, lifelong educational process.

In conclusion, developing countries are vitally concerned with national development. Consequently, they are much more concerned with economic development than environmental control. However, it should be recognised that there is a trade-off when the priorities of uses of the environment change with the stage of development of a country and the environmental quality requirements of the uses tend to become more stringent as the economy improves. Resource-conserving urbanism becomes increasingly more important in developing countries as the population increases and development occurs.

The overall objective of development is to improve the quality of life. Economic development with no environmental control leads to ecological and environmental impacts which reduce the quality of life. The major impacts of development activities should be assessed and environmental management strategies be drawn for balanced development.

If some semblance of the world of the past is to be preserved or recovered for future generations, environmental education must play a dominant role in designing the social and industrial structure for years to come.

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TECHNOLOGICAL ASPECTS OF AGRICULTURAL AND AGRO-INDUSTRIAL RESIDUE UTILIZATION

TECHNOLOGICAL ASPECTS OF AGRICULTURAL AND AGRO-INDUSTRIAL RESIDUE UTILIZATION

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I INTRODUCTION

"Waste not-want not" is a slogan appropriate to the world we live in today, especially in developing countries which account for two-thirds of the world's population and whose economies are predominently agriculturally based. In the past agricultural industries, especially those in the humid tropics, have been blessed with an abundance of production of the main economic products which inculcated a blissful unawareness of the problems of potentially pollutant residues whether they be in the form of a solid, slurry, liquid or gas. In some cases residues have been reclaimed for a variety of uses by man, either by necessity, or because the recovery and marketing of a by-product has been economically attractive.

In many of the developing countries of the ESCAP region the scale of agricultural production and the processing industries has only expanded both in area and quantity in the past forty years. Prior to this era, and even up to 20 years ago, waste residues were not of such significant quantities, and, being somewhat scattered in production, did not have the impact on the environment that is so evident today. With the expansion in cultivation of agricultural crops, new varieties, improved agronomic practices, increase in processing factories and the development of downstream processing industries, the

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water-ways and rivers have had to take prohibitive loads of pollutant wastes and mountains of solid wastes have developed which pose management and environment problems.

So as to safeguard the environment and return it to its original state, where considerable damage has already occurred, it is necessary to identify and to develop compatible industrial technology that will achieve this objective. There are many cases of existing technologies which are economic and effective and which are already in use in some countries in the region that could be adopted immediately by others. Likewise technologies already well proven in similar industries in the developed countries and other undeveloped countries, such as Brazil, could easily be transferred, providing an adequate adaptive development programme proves the schemes economically viable.

With the rapid shift in emphasis from fossil fuels to renewable resources as an energy source, many agricultural residues are becoming both technically and economically feasible as raw materials for this end-use. Moreover, renewable energy is important in strengthening the economic stability of agro-industrial processes and in possibly supplying a cheap source of energy for domestic purposes thereby reducing the impact of inflation and consequently improving the standard of living in the developing nations.

In the recent past, emphasis has also given to the potential of converting residues into food either for human or animal consumption. There are many possibilities in this field which could result in lower costs of food production and, in many cases, result in many of the countries increasing food production from the existing land area under cultivation, thus being less dependent on imported foodstuff.

This paper considers the utilization of residues from seven crops, namely, rice, sugarcane, maize, cassava, coconut, oil palm and rubber and their associated processing industries. From the end-use point of view, six categories have been identified into which most if not all the possibilities fall, viz., energy; food and animal feed; fertilizer; construction materials, paper and handicrafts, chemicals;

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and water. By identifying the appropriate technology which is economically feasible it will be possible to enhance the standard of living in the countries of the ESCAP region while at the same time protecting the environment.

II CROP PRODUCTION

Table 1 gives the current areas, total output and yield per hectare which can be used as a basis for determining the potential problems regarding wastes as a pollutant source in five countries of the ESCAP region in 1977. It is interesting to note that yield will initially determine the ultimate dimensions of the environmental problem but that the development of further downstream processing and choice of alternates and products for local consumption or export will also be of utmost significance in establishing problem areas and determining the best possible solution.

Each of the three ASEAN countries in table 1 produce to a greater or lesser extent all of the seven crops selected, while Pakistan only grows rice, maize and sugarcane, and the Republic of Korea rice and maize. In each of the five countries, the major crops in terms of production, and, consequently environmental impact are :

Thailand	Rice, sugarcane, cassava and maize
Philippines	Coconut, sugarcane and rice
Malaysia	Rubber, oil palm and rice
Pakistan	Sugarcane and rice
Republic of Korea	Rice and maize

In some cases, countries such as the Republic of Korea and Japan, which are fully developed and highly industrialized, residues such as molasses from sugar producing countries (the Philippines, Thailand, Pakistan, India, Australia and Fiji) are used as raw material inputs for potable and industrial alcoholic production. This results in downstream second generation production of agro-industrial residues which increase the problem of pollution control. On the other hand where

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production of the major end-product occurs in isolated situations, such as in Indonesia, the lack of downstream utilization of a residue, such as molasses, results in an additional pollution problem. Similarly, the import of other crude products such as cassava starch, palm oil, copra, raw sugar and maize may result in either a transfer of downstream residues of environmental importance, or potential economic benefit to the importing country.

With respect to other countries in the ESCAP region, there are similar examples that can benefit from the observations made here. In fact, Indonesia from an over-all point of view, produces all seven crops in substantial quantities and is experiencing the full range of problems associated with the development of these crops. Sri Lanka is involved in a redevelopment of its coconut industry, as are many South Pacific countries which are important coconut producers. Oil palm is being developed extensively in Papua New Guinea with the future inherent problem of controlling pollution from its mills. Finally, for India, similar problems exist, details of which are dealt with in a separate workshop paper (Vimal, 1979).

/Table 1

Table 1 Crop Production Statistics (1977)

Country	THAILAND			PHILIPPINES			MALAYSIA		
	Area ha.	Yield ton/ha.	Production ton/yr.	Area ha.	Yield ton/ha.	Production ton/yr.	Area ha.	Yield ton/ha.	Production ton/yr.
Rice	8,554,400	1.44	12,335,000	3,563,563	1.78	6,337,000	723,500	2.02	1,460,000
Sugarcane	566,575	33.43	18,941,209	482,873	60.70	29,307,787	29,792	61.75	1,839,656
Cassava	960,000	12.89	12,312,000	119,310	5.70	679,322	20,908	26.08	545,348
Maize	1,205,428	1.39	1,676,518	3,300,000	0.85	2,766,800	3,714	6.29	23,361
Oil Palm	-	negligable	-	-	negligable	-	854,990	2.44	2,090,000
Rubber	1,484,000	0.28	411,000	83,003	0.76	63,000	1,650,000	1.25	2,060,000
Coconut	439,360	1.47	644,000	2,500,000	1.18	2,960,000	356,500	2.39	850,340

Country	PAKISTAN			REPUBLIC OF KOREA		
	Area ha.	Yield ton/ha.	Production ton/yr.	Area ha.	Yield ton/ha.	Production ton/yr.
Rice	1,750,162	1.54	2,694,200	1,327,747	4.12	5,472,000
Maize	624,251	1.20	751,800	350,000	3.40	1,190,000
Sugarcane	788,178	36.87	29,056,500	-	-	-

III RESIDUES - THEIR QUANTITY, FORM AND QUALITY

Before the problems and potentials of residues can be determined, it is essential that their quantity, form and quality be assessed. This will enable the problems, if any, to be defined accurately, and the adoption of economically feasible technology for the utilization of various residues to be appropriate for a particular country, region or locality.

Agricultural and agro-industrial residues occur in three basic forms, viz., solid, liquid and gas, which are either primary, secondary or tertiary in origin, depending on the degree of development of the industry concerned.

a. Quantities

The quantities of each particular residue produced appear to have a relationship to the main end-product which is statistically reported in each country's yearly records. From the production to by-product (residue) ratio, given in table 2, it is possible to determine the quantities of each residue which might be of current or future economic and environmental importance.

Before illustrating the use of this data, it is necessary to point out that major agricultural industries based on these seven crops produce both pollutant and non-pollutant types of residues and that in such crops as sugarcane a potentially pollutant residue in the form of molasses is currently of such economic value that it usually poses no threat to the environment, while in the case of rice straw, because of its nature and the fact that it is used as an animal feed or fertilizer, it is a non-pollutant residue.

In some cases, it is possible to estimate the total effluent discharge of an industry, such as, for oil palm and rubber in Malaysia where there is 5.75 million and 50.37 million tons of liquid waste, respectively, being discharged into Malaysian water-ways yearly.

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Table 2 Production Ratios of By-products (Residues)

Oil Palm (crude mill)

A.	Crude oil	1.000
	Fresh fruit bunch	5.000
	Effluent (6% solids)	2.750
	Presscake fibre	0.605
	Kernel	0.210
	Kernel oil	0.085
	Kernel cake	0.085
	Kernel shell	0.235
	Empty bunch	1.200
	Sludge oil	0.050-0.150
	Sludge solids(12% H_2O)	0.138
	Methane production	76.2m^3
B.	Fresh fruit bunch	1.000
	Crude oil	0.200
	Effluent (6% solid)	0.550
	Presscake fibre	0.122
	Kernel	0.042
	Kernel oil	0.017
	Kernel cake	0.017
	Kernel shell	0.047
	Empty bunch	0.240
	Sludge oil	0.006-0.030
	Sludge solids	0.078
	Methane production	380.9m^3

Sugarcane (raw mill)

A.	Sugarcane	1.000
	Sugar	0.080-0.120
	Bagasse	0.289
	Tops	0.099
	Molasses	0.280-0.370
	Mud	0.020-0.050
	Waste water	0.096
B.	Molasses	1.000
	Alcohol	0.270
	Stillage	2.700
	Cooling water	5.400
C.	Sugarcane	1.000
	Alcohol	0.088
	Bagasse	0.280
	Stillage	0.880
	Cooling water	1.760
D.	Molasses	1.000
	Sugarcane	4.366
E.	Alcohol	1.000 litre
	Sugarcane	15.900 kg
	Molasses	3.642 kg
	Cooling water	0.01140m^3
	Stillage	0.00570m^3

Cassava

A.	Chips	1.000
	Tons chips	1.000
	Fresh root	4.630
	Recovery	21.6%
B.	Starch	
	Starch	1.000
	Pulp	7.536
	Peelings	0.480
	Fresh root	5.000
	Wash water	22.680
	Fruit water	4.400
C.	Alcohol	
	Alcohol	1.000
	Pulp	9.248
	Wash water	12.335
	Peelings	1.068
	Cooling water	12.105
	Stillage	8.203
	Fresh root	7.519

Coconut

Copra	1.000
Nuts (1.2 Kg)	2.898
Husk	0.944
Shell	0.438
Dessicated coconut (360 gm/1.2 Kg nut)	0.870
Coconut oil	0.63
Copra cake	0.26
Coir	0.197
Coconut water	0.533
Dessicated coconut waste water	
1 ton nuts - 3850 litre	
1 ton dessicated powder - 12850 litre	
Coir (1000 husks = 400 Kg produce 87.6 Kg coir)	

Rubber

Dry rubber	1.000
Liquid effluent	24.450
Rubber seed	0.080
seed meal	0.018
seed shells	0.028

Rice

Padi		1.000
Straw		2.600-3.960
Bran		0.050-0.080
Husk		0.200-0.250
White rice		0.690-0.740
Bran oil		0.010-0.130
Straw	Thailand	3.17 - 3.96
	Indonesia	2.74 - 3.43
	Philippines	2.60 - 3.25
	Average	3.28
Maize		
Grain		1.000
Stem		3.200-4.328
Cobs		0.860
Husk + Skins		1.000
Stem	Thailand	3.33 - 4.67
	Philippines	3.21 - 4.29
	Indonesia	3.10 - 4.14
	India	3.16 - 4.21

Note: 1. Stillage - slopes - waste water.

2. The underlined product is the base unit.

This represents a total BOD load of 1.265×10^5 tons for oil palm and 1.511×10^5 tons for rubber which is a very serious environmental problem for Malaysia. Considering the detrimental effects of these industries, an effort by the Malaysian Government has been undertaken to establish standards, and to implement control measures to ensure a return to a pollution free environment.

Where a residue is of impending greater economic value as is the case of molasses (a raw material for the production of alcohol fuels), it is possible to determine a country's or region's potential savings in foreign currency if this commodity is diverted to this new end-use: For instance, if Pakistan were to convert 50 per cent of its sugarcane production into raw sugar, it would have approximately 600,000 tons of molasses available per year which could be transformed into ethanol as a 20 per cent substitute for gasoline (as is being done in Brazil). The savings in foreign exchange (assuming a value of U.S. 0.25 cents per litre) would be about US$ 75 million which is about 3 to 4 per cent of Pakistan's current export earnings and about 8 per cent of Pakistan's current expenditure on imported petroleum products.

Aside from issues of pollution and economic importance, table 2 also allows for a reasonable guideline as to the feasibility of setting up a particular process to utilize a residue for a certain end-use. Consideration has been given by many authors to the use of cellulosic residues, such as corn cobs and stalks and rice straw, for the production of furfural. However, there is a need to assess the availability of sufficient reliable supply to justify the high capital investment involved. The same premise applies to the suggestion that various fibre residues such as bagasse, oil palm press fibre, and empty bunch fibre are suitable raw materials for paper production. Therefore, the conversion ratios given in table 2 do not enable a complete evaluation of the potential use of agricultural products as other factors such as existing utilization, concentration of production, transport and acquisition logistics have to also be considered. This will be dealt with in greater detail later.

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Another use for the data in table 2 is that it can be matched with details of the efficiencies of utilization of certain residues in order to redesign mills to improve energy utilization efficiency and hence make more surplus energy available for further downstream, or alternative processes.

As with other tables in this section, this only provides a guideline and the figures given might vary from country to country, region to region, and even factory to factory. For detailed and accurate feasibility studies and designs, each case must be studied separately. One of the main problems is that there still are many factors to be taken into account by each case of agro-industrial production.

b. Chemical composition

The chemical characteristics of most of the residues considered in this paper have been reasonably well documented for both liquids and solids which are of economic or environmental importance.

The liquids are dealt with by Thanh (1979) within which tables for effluents from the cassava, oil palm, rubber, sugarcane and coconut industries provide data on COD, BOD, pH, nitrogen, phosphorus, total solids, suspended solids and temperature. In some cases, such as dessicated coconut plant waste water, the phenol and volatile suspended solids content are given. For palm oil waste, the oil level is given. This information is necessary for the environmental engineer in designing an economic and efficient pollution treatment system to meet the standards that are legally required in each country. In addition, from an end-use point of view, it is useful in assessing the potential of the effluent, once treated satisfactorily, as a fertilizer, as an input raw material (recycled water), or as a source of supply for another downstream process.

For solid wastes, table 3 provides an evaluation of the organic components and total inorganic content which indicate their potential as an end-use material for fuels, chemicals such as activated carbon, furfural, enzymes or production of alcohols. The high ash

/content

Table 3 Chemical Composition of Solid Crop Residues (Dry Basis)

Residue	Cellulose %	Lignin %	Pentosans %	Ash %	Others %
Rice					
Straw	-	-	-	-	-
Hulls	41.00	20.00	19.50	18.00	-
Maize					
Stalks	40.00	35.00	25.00	-	-
Cobs	36.00	32.00	32.00	-	-
Sugarcane					
Bagasse	56.00	18.00	25.00	1.00	-
Oil Palm					
Press fibre	40.00	21.00	24.00	5.00	10.00
Empty bunch	34.50	24.00	23.50	5.00	10.00
Coconut					
Husk	44.40	29.30	16.90	3.30	-
Husk dust	51.40	39.20	11.00	4.90	-
Coin	62.30	30.90	9.60	2.70	-
Trunk	66.70	25.10	22.90	2.80	-
Petiole	64.40	16.20	18.60	4.70	-
Leaves	47.10	27.70	11.60	8.10	-

content of rice hulls is mainly silicon (SiO_2 at 90 per cent) which must be considered when deciding upon its potential end-use.

c. Nutritional value

Residues of these agricultural crops have to some extent been used as animal feeds for centuries; but it was not until recently that their full potential became evident. Many research workers during the last three decades have evaluated the multitude of residues from this standpoint. The nutritional values given in table 4, have been largely derived from a comprehensive assessment of such materials by Hutagalung (1977) and Muller (1975).

As will be discussed later, there are a number of excellent economically viable prospects for converting residues into animal feed and indirectly into human food. Cassava leaves for example are very high in protein and could be a valuable source of carotine also. Quite a number of the residues included are currently used as animal feed components, viz., rice bran, palm kernal cake, copra meal and molasses. Others show potential as non-traditional feed sources, viz., rubber seed meal. This data only gives an initial indication as to a particular residue's potential. More information such as the digestibility of componants and feed/product conversion ratios will be needed for a full evaluation. Additional studies on the toxicology of these materials will also be necessary.

d. Energy values

Even before the advent of fossil fuels, crop residues had been used as energy sources. The energy value of materials such as sugarcane bagasse, palm oil fibre and kernel shell, coconut husk and shell, and rice husk have been recognized and have resulted in processing industries that are more than energy self-sufficient. Table 5 presents the energy values of residues and traditional fossil fuels to enable an evaluation of the potential energy balance in any modification or new design for an industry using these crops as an energy source.

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Table 4 Nutritional Composition of Crop Residues for Animal Feed

Residue / Constituent	Crude Protein %	Ether Extract %	Crude Fibre %	Nitrogen Free Extract %	Ash %	Moisture %
Rice						
Rice straw	0.50 - 5.90	0.70 - 2.10	26.40 - 42.50	47.70 - 18.00	12.70 - 21.30	12.0 - 10.0
Rice hulls	2.50	0.90	36.20	33.90	16.00	10.50
Rice bran	13.40	20.00	10.10	34.70	9.3	8.50
Broken rice	7.50	1.10	7.00	88.00	5.00	1.40
Maize						
Leaf	7.80	2.30	25.40	44.10	14.20	7.20
Cob	2.70	0.60	32.70	59.60	2.40	7.00
Husk	5.10	1.30	30.00	53.60	5.8	4.20
Stalk	6.10	1.60	36.80	46.90	8.6	
Sugarcane						
Tops	6.50	2.10	34.00	40.80	6.10	10.50
Bagasse	2.80	0.60	46.40	36.00	3.20	11.00
Pith	1.90	1.00	45.00	34.20	7.90	10.00
Filter mud	10.40	10.90	12.00	42.70	23.90	74.00
Molasses	4.20	0.00	0.00	87.20	8.60	26.00
Stillage (Wet basis)	16.60	0.20	0.60	60.90	21.80	93.40
Cassava						
Tuber (chips)	1.55	2.45	2.87	80.69	1.38	12.98
Leaves	25.00	6.30	15.91	37.30	5.50	10.00
Pulp	1.80	0.20	5.00	65.00	18.00	10.00
Oil Palm						
Palm kernel cake	17.60	14.32	15.69	38.47	3.02	10.90
Sludge solids	10.20	16.60	11.40	40.10	11.30	10.60
Press fibre	4.00	21.00	36.40	29.60	9.00	13.80
Rubber						
Seed (expellar)	28.00	11.50	13.90	35.50	4.50	6.60
Seed (solvent)	30.00	8.50	6.00	46.30	4.60	4.60
Kernel	18.00	52.30	1.90	25.20	2.60	30.00
Coconut						
Oil meal (solvent) (Iraq)	20.50	0.40	26.10	46.00	7.00	6.60
Oil cake (expeller) (Malaysia)	20.00	11.70	8.30	52.80	5.90	11.20
Coconut water(Nigeria)	4.40	6.00	6.50	70.80	12.30	94.80
Ceir dust (Tanzania)	2.30	0.70	34.20	55.20	7.60	12.90

Table 5 Energy Values of Selected Fuels and Agricultural Residues

Fuel/Residue	Moisture Content	K.cal/kg.	K.cal/m^3	Btu/lb.
Sugarcane bagasse	12%	3,860	-	7,821
Sugarcane bagasse	52%	2,220	-	4,000
Rice husk	10%	3,340	-	6,000
Rice husk charcoal	0	6,111	-	11,000
Palm oil fibre	30%	1,512	-	2,700
Palm oil fibre	10%	3,950	-	7,000
Palm kernel shell	6%	1,960	-	3,500
Palm empty bunch	60%	560	-	1,000
Coconut husk	-	-	-	-
Coconut husk charcoal	6%	-	-	-
Coconut shell	13%	4,010	-	7,560
Coconut shell charcoal	6%	7,860	-	14,148
Diesel No.1	0	10,878	-	19,580
Gasoline	0	11,267	-	20,280
Fuel oil No.2	0	11,183	-	20,129
Coal	0	7,215	-	12,987
Ethynol	5%	9,269	-	16,684
Methane	0	13,243	846	23,837
Methynol	0	6,383	8,525	11,489
Biogas	0	-	5,517	-
Pyrolysis gas	0	-	4,450	-
Wood (soft)	10%	4,500	-	8,100
Coconut stem charcoal (briquette)	0	9,600	-	17,280

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Moisture content will have an important effect on the resultant energy recovery and downstream use of rejected heat. However, the effect of carbonization of charcoal results not only in a greater energy value but eliminates the problem of air pollution if direct firing of the drying systems is used.

Other residue energy values should also be evaluated if they are to be considered as a fuel. Other factors such as collection, supply consistency and value of condensate by-products (controlled carbonation systems only) should also be taken into account.

Another source of energy which is normally neglected is the rejected heat from a particular process system. Most low calorific fuel boilers have until now been designed to consume as much of the available fuel (bagasse or oil palm fibre) as possible because the residue was a nuisance to discard. Hence these boilers were very low in efficiency, with the result that about 50 per cent to 60 per cent of the available energy is rejected. The rejected energy is in the form of flue gases which in an induction fired boiler can reach 350-400^{o}C with a moisture load depending on the water content of the input material. Other sources of waste energy are in the form of rejected heat from condenser cooling water or air depending on the design of the power plant.

e. Form

Another important aspect of residues is their physical form because form is related to the potential end-use of the residue. The various forms of residues are given in table 6.

Liquid in table 6 is divided into liquids which contain suspended solids, whether actual solids or immiscible droplets such as those of oil, or colloidal solids and those without suspended solids. It is often a desirable feature to fractionate the residue into appropriate sub-fractions with a more limited biochemical or chemical availability for ease in processing.

/A

Table 6 Physical Forms of Residues

Liquid	) with suspended solids)) without suspended solids)	dilute, concentrated
Slurry		
Solid	) structured) unstructured	
With mineral/dirt contaminant		
With toxic metal contamination		
With organic toxin contamination		
With biological/micro-organism contamination		
Hot/ambient		
High carbon	) fermentable) non-fermentable	
High N		
High P		
High special nutrient components		
High inert fraction (silica/silt/clay)		

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A slurry, that is a solid and liquid mixture which can be poured, is a very common form of residue but may be one of the most difficult to process. A typical slurry is that of cow-dung, but others may be high mineral slurries in the form of sludges from industrial processing.

For solids there is a difference between them being structured and unstructured. The structured solids may require comminution or separation on the basis of particle size which may result in the separation of the physical and chemical characteristics of the components.

In all these types of residue, there is the question of the dilution factor. In liquids this dilution factor is usually water, although it may be an oil. Similarly, with solids the dilution factor might be due to inert matter such as sand, clay or other inert mineral matter or it may be in the form of contamination such as bark and cork particles, lignin components or other useful cellulosic residues. One of the most important features which constrain the use of cellulosic residue is the presence of silica in the material.

f. Pollutant properties

With respect to liquid residues, their chemical and pollutant properties are dealt with in another workshop paper (Thanh 1979). The problems of contamination by dirt or solid plant particles and toxic substances such as inorganic compounds (mercurial or arsenic salts and cyanide) and organic compounds due to the presence of such material as cyanogenic glucocides and toxin development during waste storage must be taken into account so as to enable the correct process and usage to be determined.

Having considered the quantities, forms and qualities of the various types of residues associated with the sampled crops, it is now appropriate to discuss the potential end-uses from an economic standpoint.

/IV.

IV END USES

From the residues of the crops sampled in this paper there are a multitude of possibilities as to how they may be utilized as has been amply reported by Bhushan (1977), Stanton (1977), Stout and Loudon (1977), Baret (1977) and Muller (1978) to name a few cources. Considerable research, both private and government supported, has been and is being carried out to investigate the technology and development of new processes to convert and utilize all forms of residues which may or may not be of a pollutant nature. There also exists practices, which may be traditional or have been adopted for many eyars, that efficiently utilize residues thus producing an economic by-product which may be saleable or complementary to the production of the main product.

The possibilities reported previously, in many cases, do not take into account the stage of development the technology is at, its origin and the economic and social consequences of adopting such technology. It should be ntoed that practices suitable for temperate climates and temperate climate crops and suitable for highly sophisticated fully developed countries are probably not suitable for the underdeveloped countries of the Asian and Pacific region.

The approach of this paper is to identify potentially economic and socially acceptable practices for crop residues which are suitable for this region. A principle objective of the paper is to identify and promote the economic utilization of residues in order to minimize or eliminate a potentially pollutant waste which is, or will become a hazard to the environment. Such an approach will enable the cost of pollution control to be partially covered by use of the residue or even increase the industry's profits if the by-product is a valuable one.

As a basic assumption, the main end-use product must be firstly identified for each particular crop in order to determine what materials are residues that may be converted into saleable by-products. Table 7 gives a proposed assessment of the main products from the seven crops concerned.

/Table 7

Table 7 Main Products Derived From Seven Agricultural Crops

Crop	Product
Rice	White rice
Maize	Maize grain
Sugarcane	Raw sugar
Cassava	Chips/pellets starch glucose alcohol
Coconut	Copra coconut oil dessicated coconut
Oil palm	Crude oil palm kernel
Rubber	Drived rubber liquid latex

It must be emphasized that in some cases further downstream development such as has occurred with oil palm in Malaysia, coconut in the Philippines, and sugar in Thailand and the Philippines, has resulted in additional end-products, but that these are not considered here.

It is proposed that all types of residues be considered as potential end-uses under six categories namely, energy good and animal feed, fertilizer, construction paper and handicrafts, chemicals, and water. Within each category the potential of a residue for an end-use will be classified on a time base as :

(a) currently in use
(b) immediate potential
(c) mid-term potential
(d) future possibilities

/Before

Before evaluating the potential end-uses of various agricultural industries, a brief description of the existing industries and their processes should be considered. For this purpose the following flow charts (figures 1 to 12) illustrate the existing processes and, in the case of coconut and sugarcane, the potential end-products that can be derived from these raw materials. These figures will be referred to in the discussion on the various categories of end-uses and the importance of each product in relation to its possibilities within this region.

a. Energy: The potential of residues as an energy source

With the current trends in the very volatile cost and supply of fossil fuels which has beset the world since 1973, there has been in many countries, and particularly those lacking an abundant supply of petroleum resources, an ever-growing awareness of the need to consider energy conservation. This has resulted in a change to alternative renewable resource fuels even when they are of a lower Net Calorific Value (N.C.V.). With the dramatic increase in expenditure on imported energy due to spiralling oil price hikes, many countries in this region such as Pakistan, Thailand and the Philippines are facing a large strain on foreign exchange, increased inflation and possible lower standards of living.

In the existing agricultural industries associated with these seven crops, there is a significant potential for the use of residues as an energy source, which can be utilized directly within the industry, in an annexed process plant, or in a nearby secondary industry.

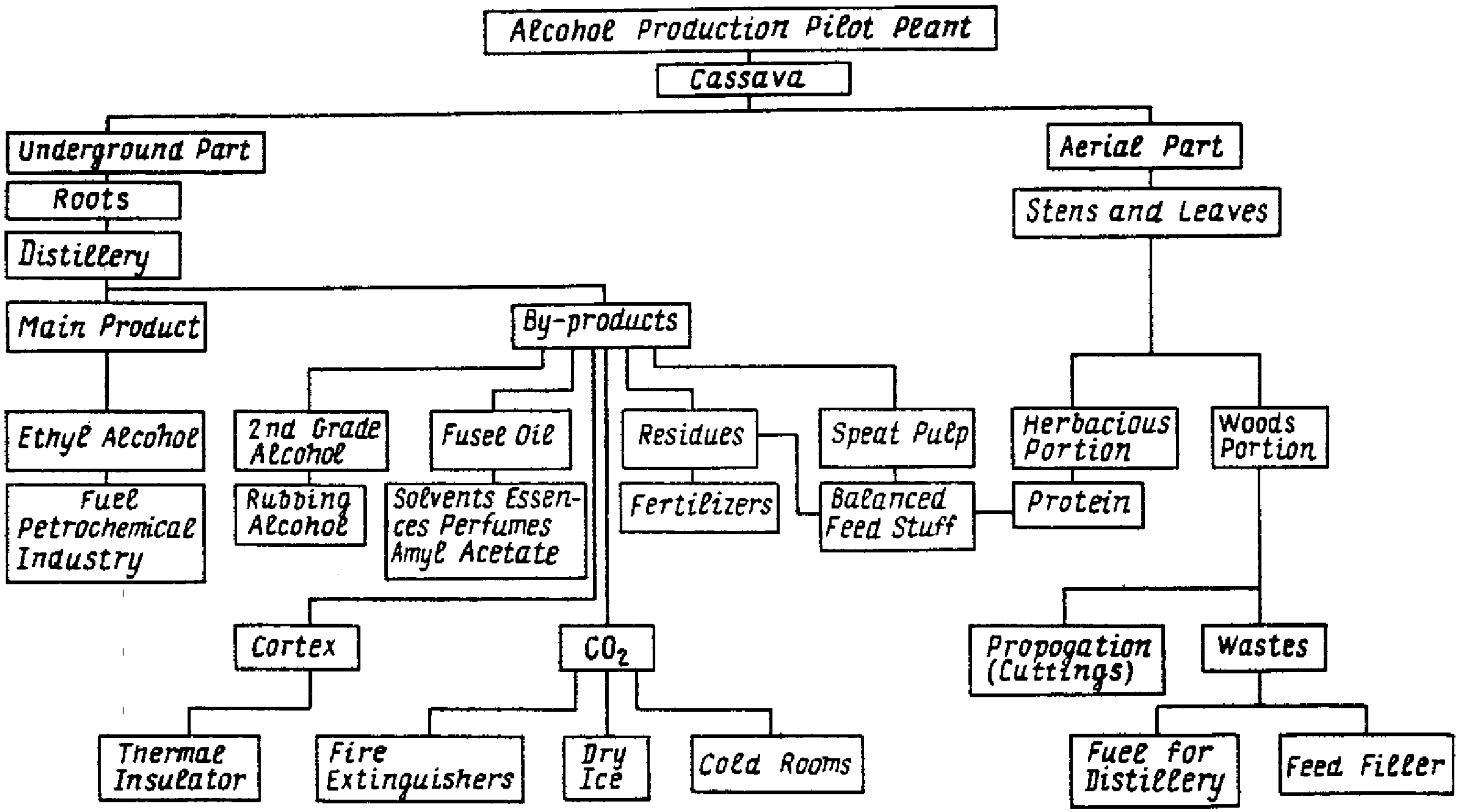
(1) Current uses

(a) There are a number of examples of agricultural residues being used as an energy source which have been established for almost 80 years (as is the case for sugarcane) or 60 years (as is the case of oil palm processing). Both sugarcane and oil palm processes are self-energizing and due to the large quantities of resources available, relatively inefficient boilers and process systems have been used so as to avoid surplus waste residues and to avoid higher capital costs.

/Sutanto

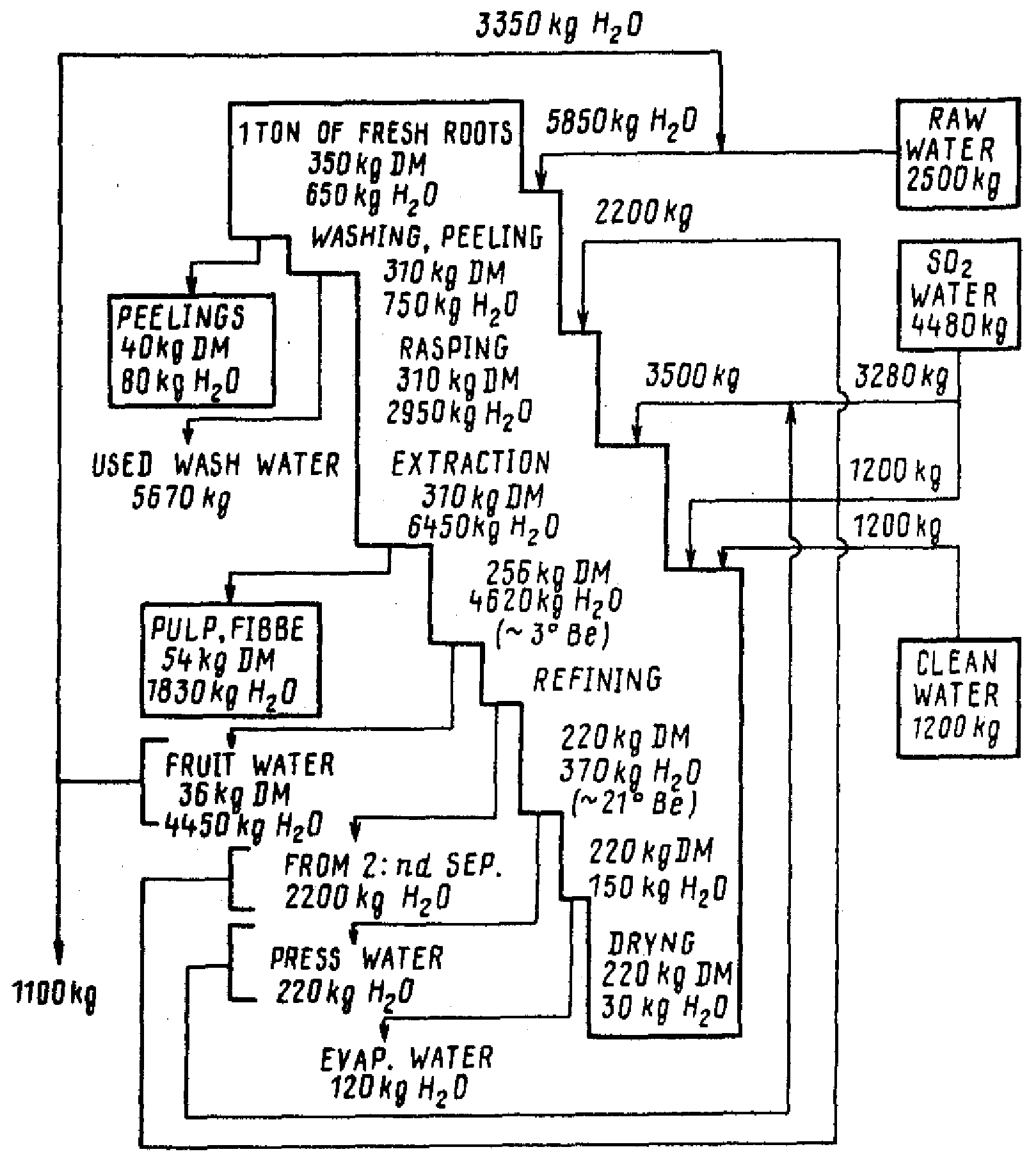
Figure 1 ALCOHOL PRODUCTION AND BY-PRODUCTS FROM CASSAVA

FIGURE 1

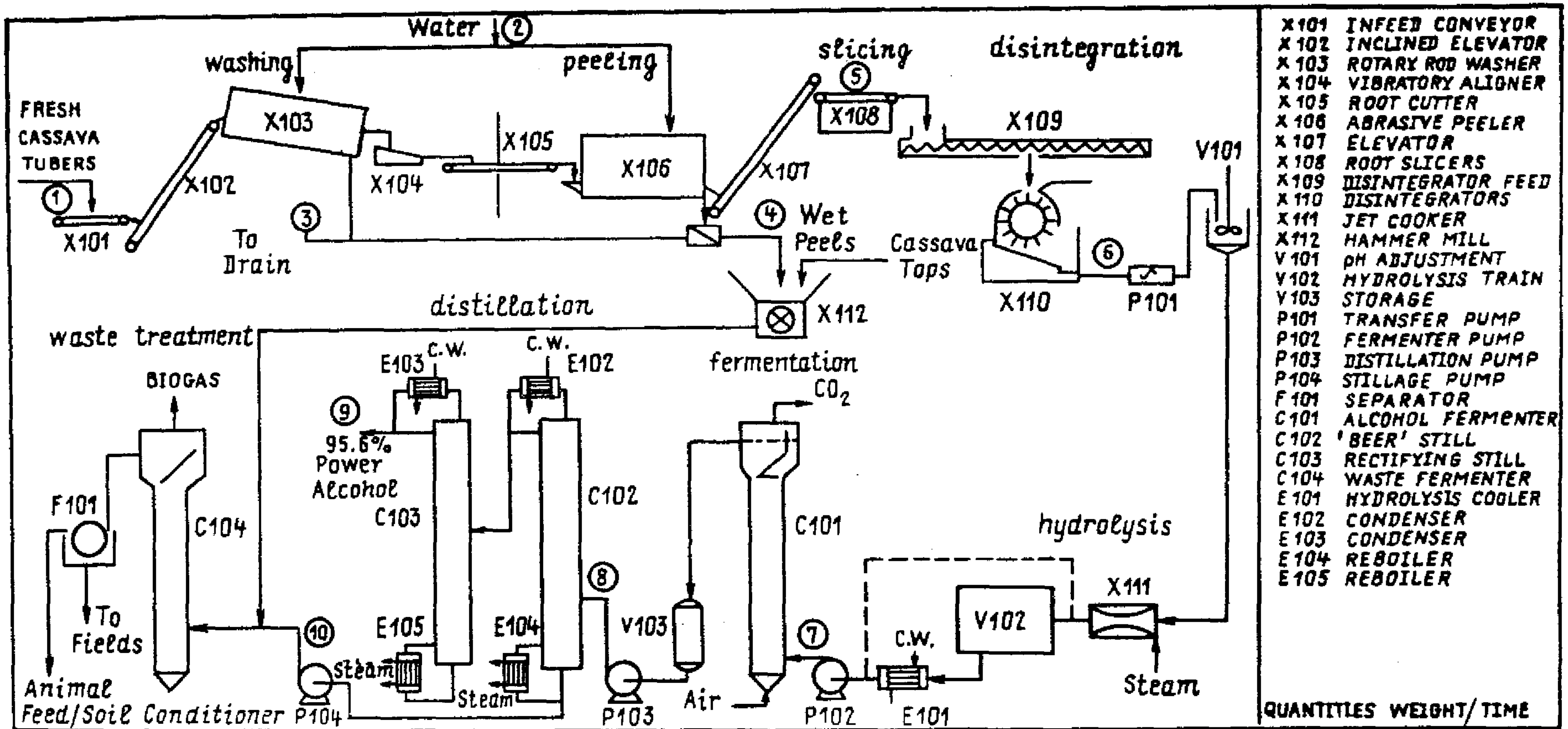


Source: CIAT Cassava Newsletter

Figure 2 TYPICAL MATERIAL BALANCE FOR AN ALFA-LAVAL MANIOC STARCH PLANT



Source: - AltaLaval Technical Bulletin

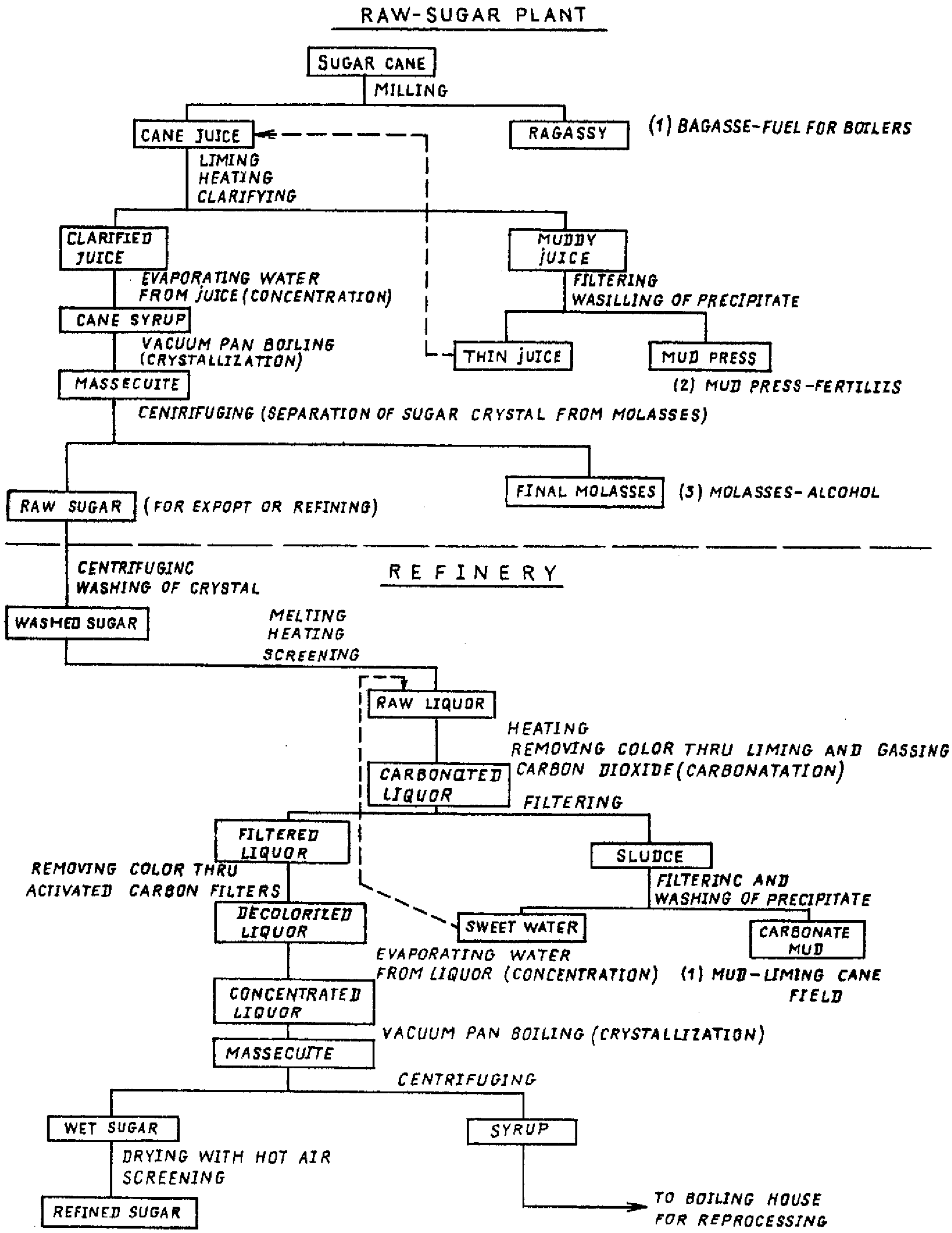


QUANTITIES WEIGHT/TIME

STREAM NO.	1 FRESH TUBERS	2 WASH WATER	3 WASTE WATER	4 WET PEELS	5 PEELED TUBERS	6 CASSAVA PULP	7 FERMENTER FEED	8 DISTILLATION FEED	9 POWER ALCOHOL	10 STILLAGE
CARBOHYDRATES	30.0	—	—	2.7	27.3	27.3	0.8	0.8	—	0.8
CELLULOSE	2.0	—	—	0.5	1.5	1.5	1.5	1.5	—	1.5
PROTEINS	3.0	—	—	0.8	2.2	2.2	2.2	2.2	—	2.2
HCN	0.02	—	—	0.016	0.004	0.004	—	—	—	—
WATER	65.0	164.0	161.0	10.2	57.7	92.0	105.2	105.2	0.6	104.6
FERM. SUGAR	—	—	—	—	—	—	26.5	—		—
ALCOHOL	—	—	—	—	—	—	—	12.7	12.7	—
TOTAL	100.0	164.0	161.0	14.2	88.7	123.0	136.2	122.4	13.3	109.1

FIGURE 3: SIMPLIFIED FLOWSHEET FOR CASSAVA ALCOHOL PRODUCTION (AGRO-INDUSTRIAL CONCEPT)
Source: McCam (1978)

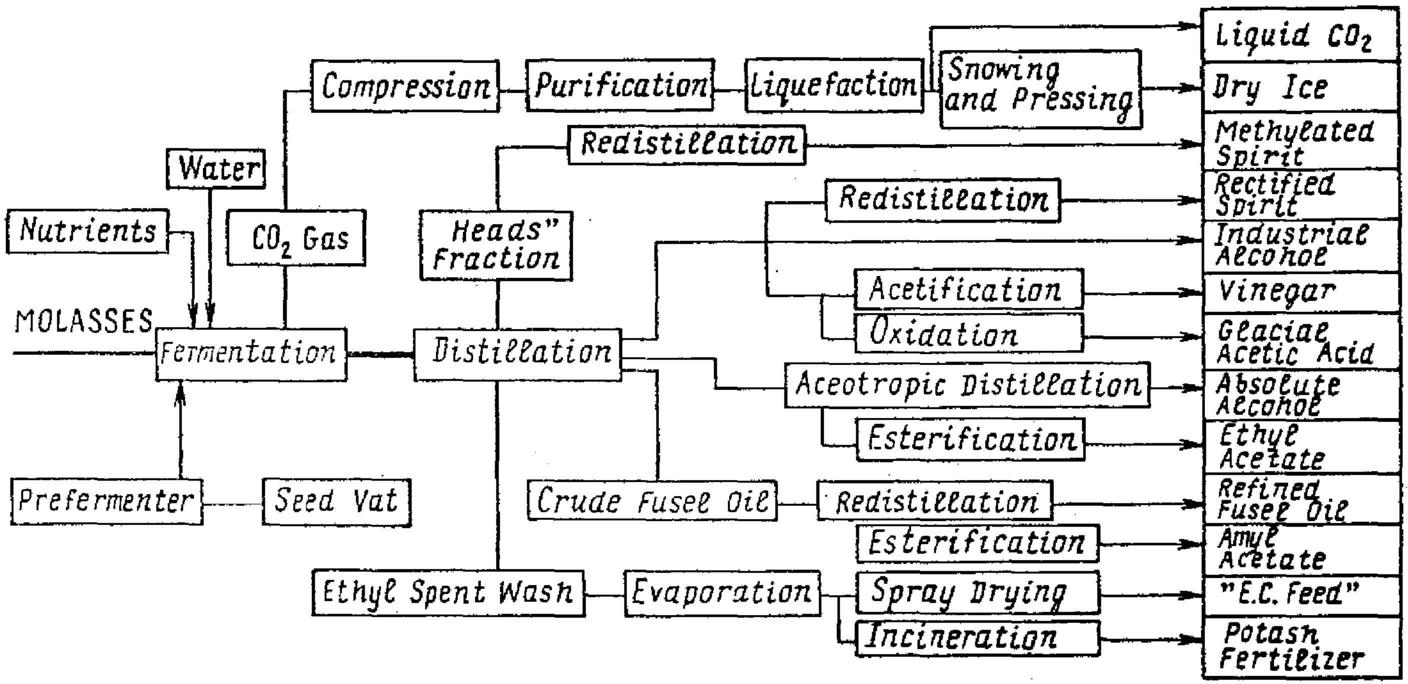
Figure 4 RAW AND REFINED SUGAR MANUFACTURE FLOW DIAGRAM



source:- PHILSUCOM Republic of Philippines

FIGURE 5

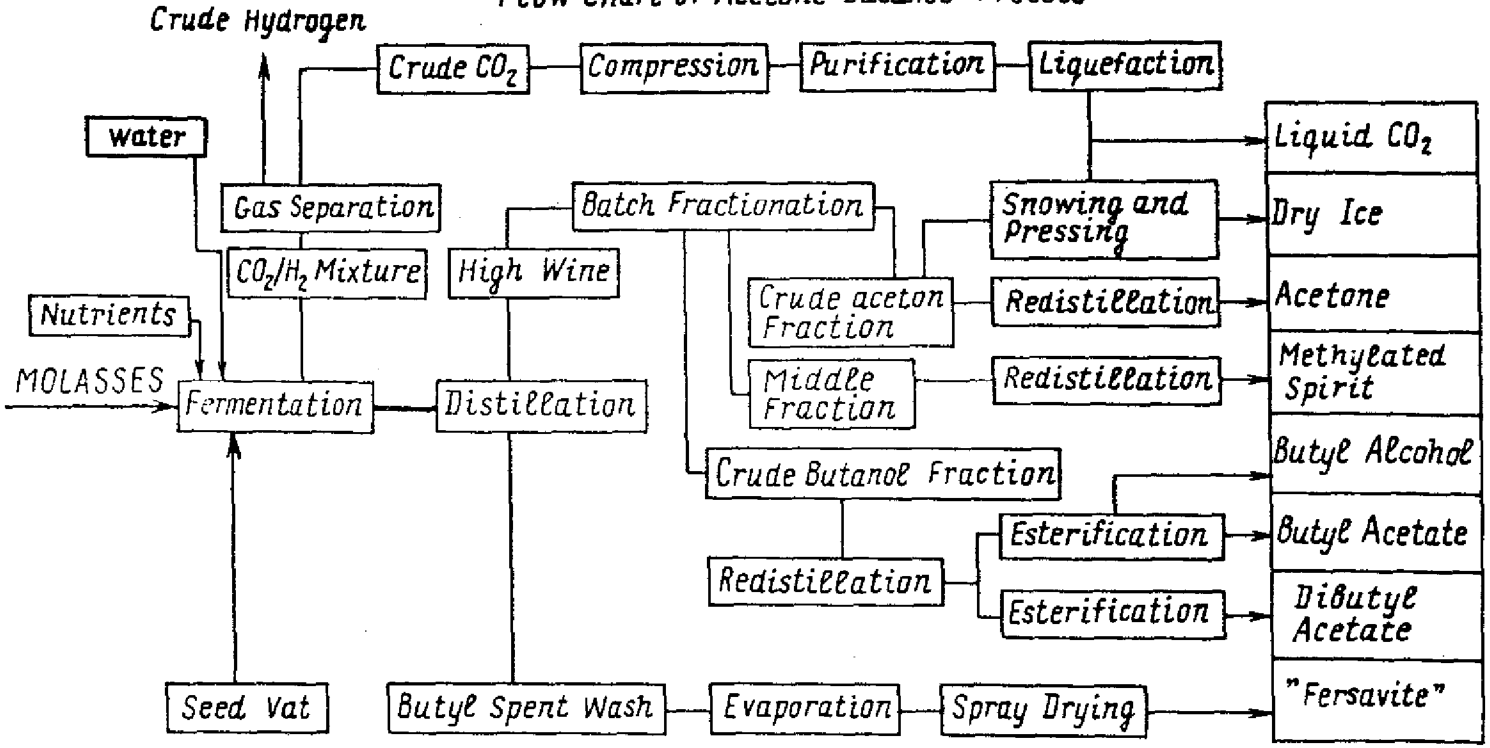
Flow Chart of Ethyl Alcohol Process



Source: Bates (1964)

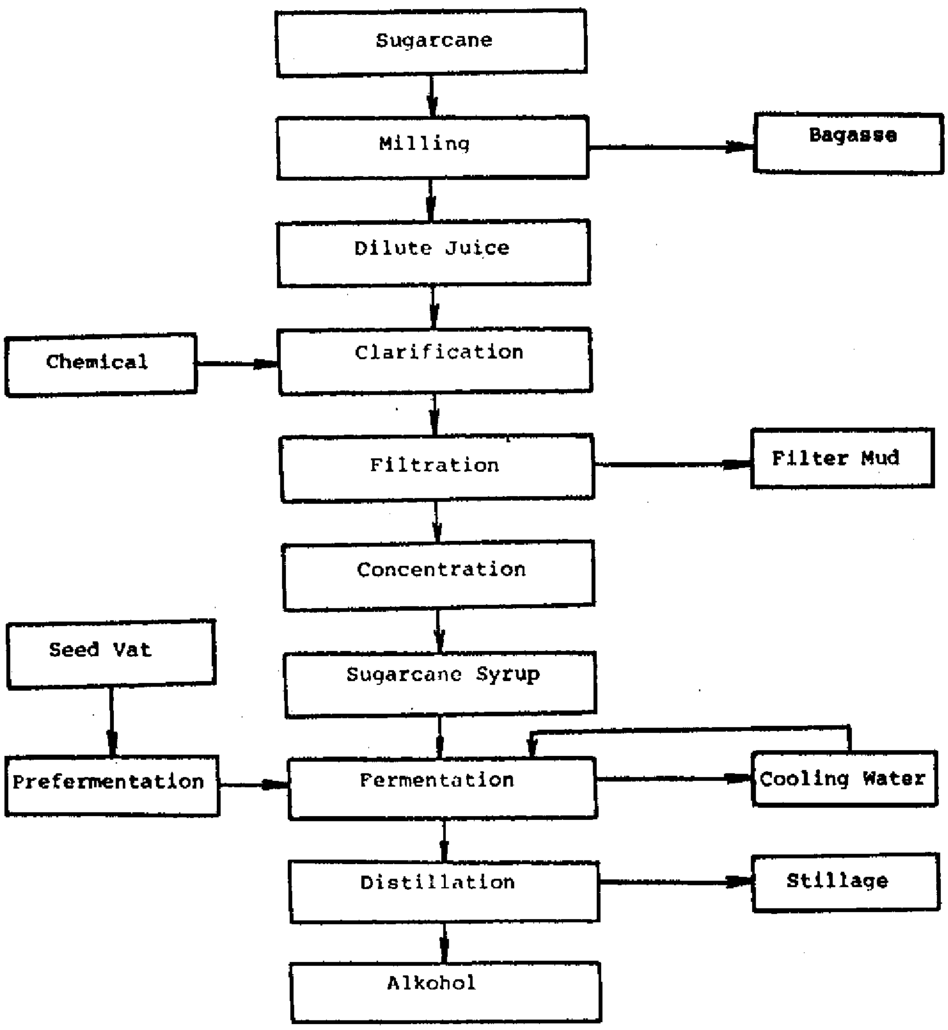
FIGURE 6

Flow Chart of Acetone Butanol Process



Source: Bates (1964)

Figure 7 Ethanol From Sugarcane Process Flow Chart



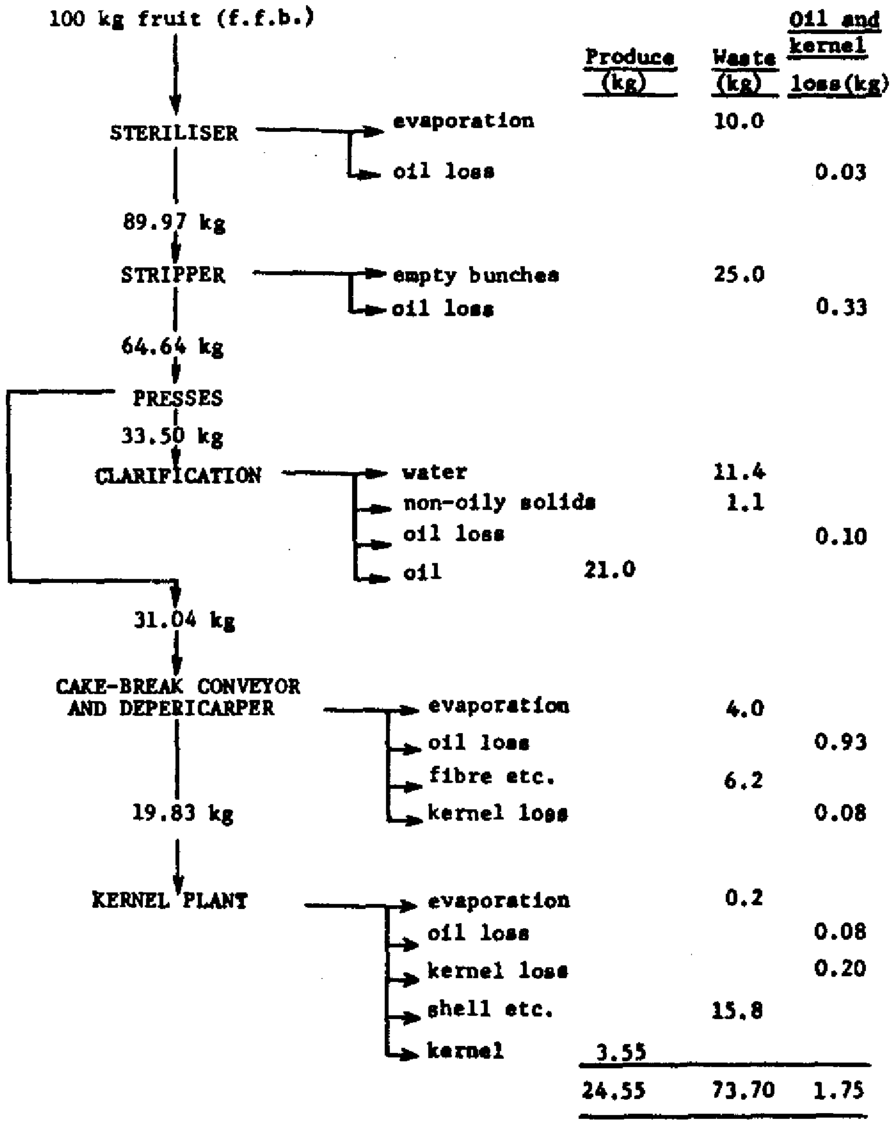


Figure 8 Palm Oil Mill Process Flow Chart

Source: Turner (1974)

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Figure 9 CENSOR III

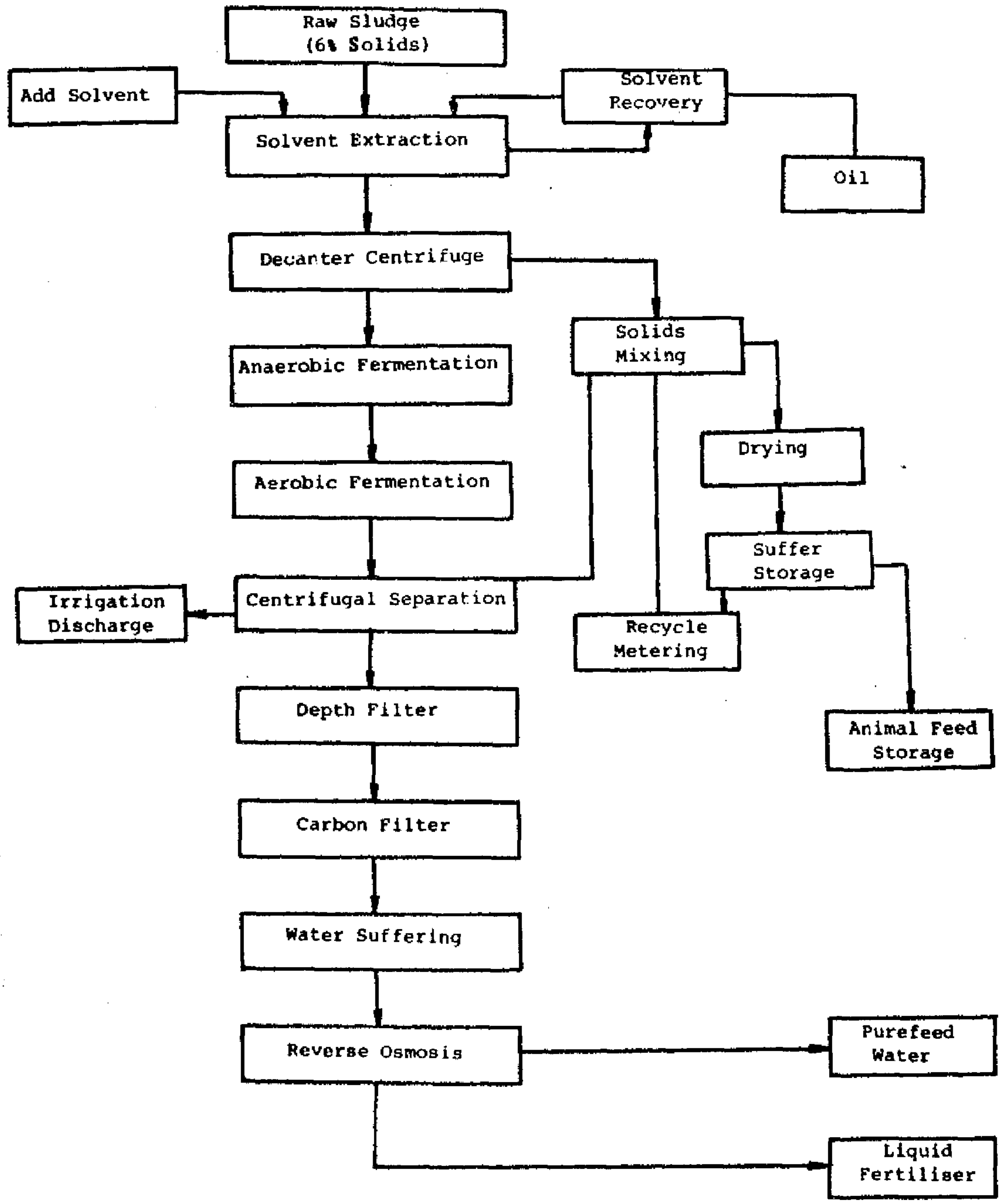

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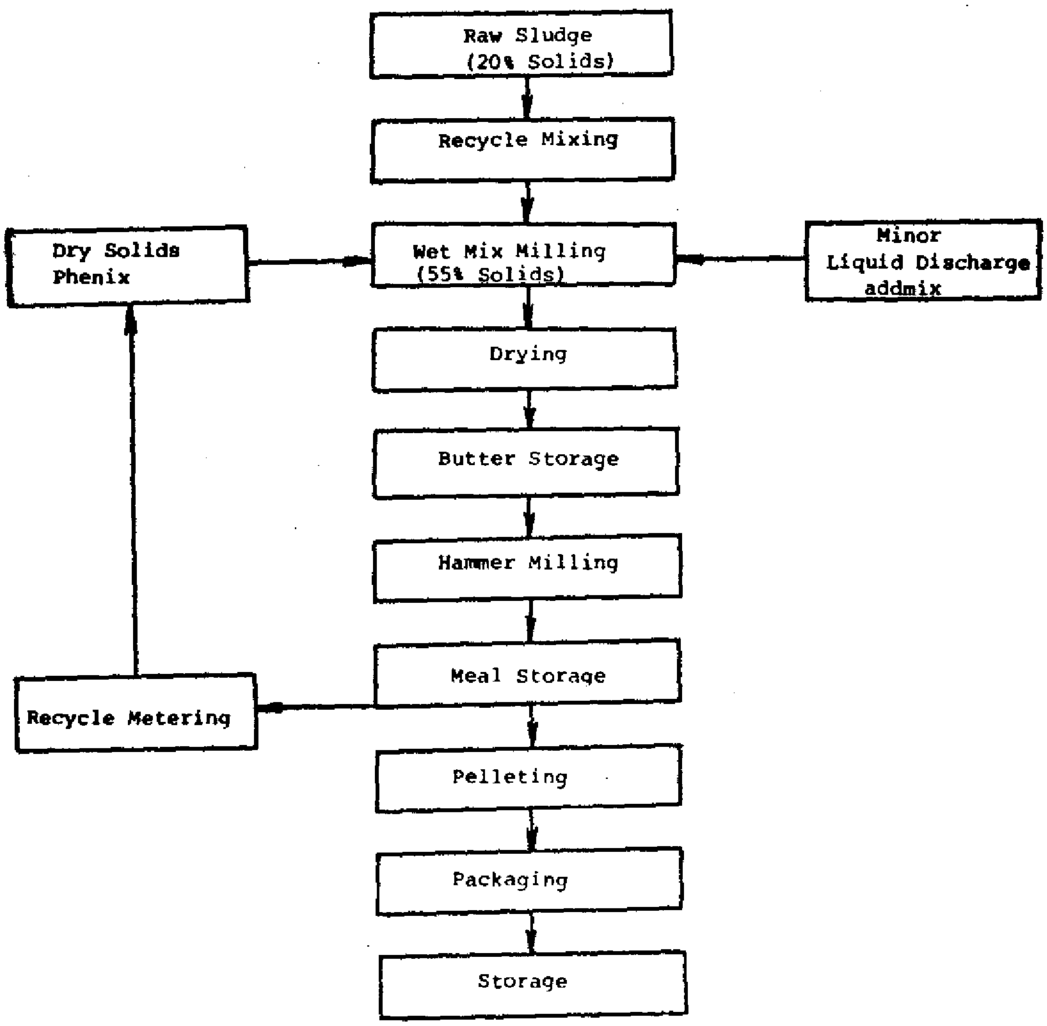
Figure 10 CENSOR IV



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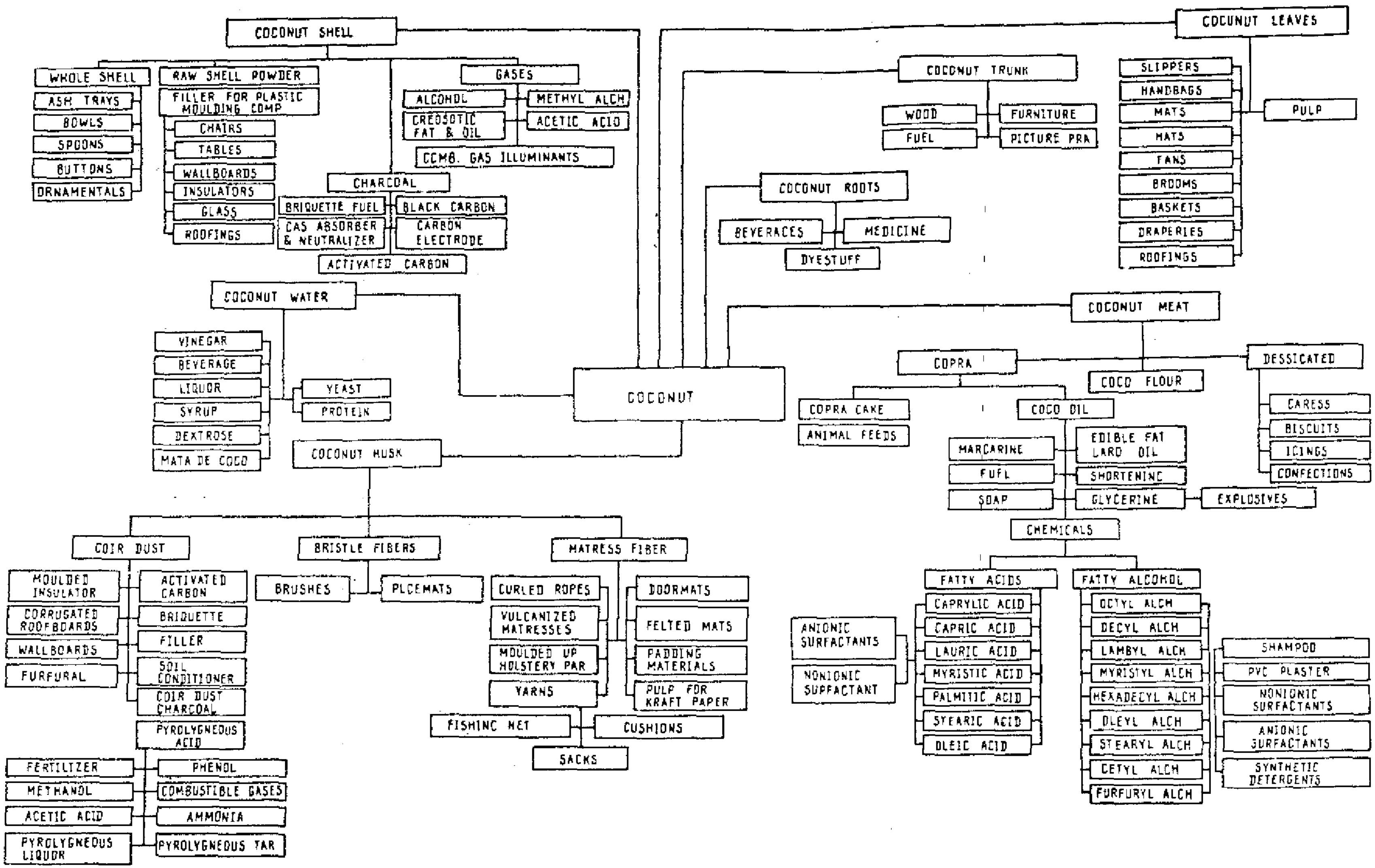

Figure 11 Economic Uses of The Coconut

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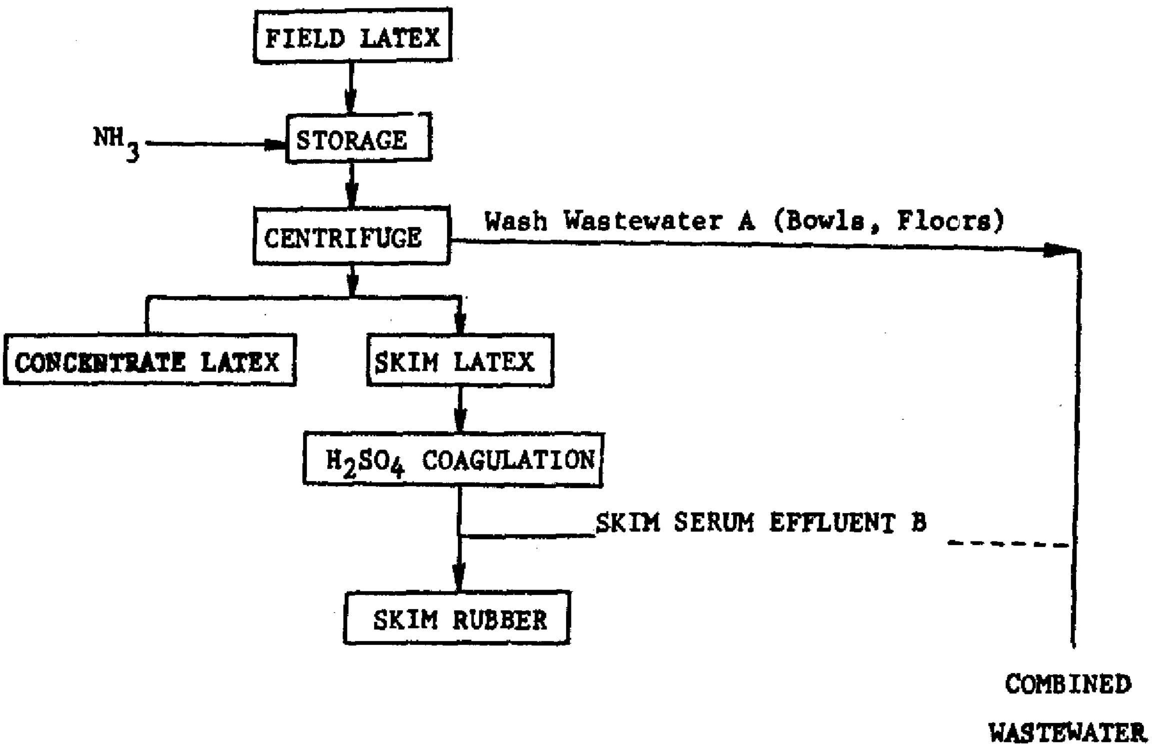

Figure 12 Latex Concentrate Process

Source: Thanh (1979)

Sutanto (1979) has estimated that the Net Heating Value (N.H.V.) available from processing 100 tons of oil palm fresh fruit bunch (ffb) and 100 tons of sugarcane is 1.18 mill. Kcal (2.1 mill. Btu.). As both industries require 455 kg (1,000 lb.) of steam to process 1 ton of ffb or 1 ton of cane there is a surplus of 1,300 kW electricity for every 100 tons of ffb or cane processed. Based on this data, if all the solid wastes in oil palm millc in Malaysia were to be converted into electricity, a total of 0.75 million K.V.A. surplus electricity would be available.

(b) The coconut industry throughout the region generally uses husk and shell as a fuel source for copra drying. Work in the Philippines has attempted to improve the quality of copra and supply domestic fuel to villagers by promoting the production of charcoal from shell and husk.

While the pit method has been established for a considerable time, newer and more efficient techniques are now available as reported by Tamalong (1978) and more recently Estudillo (1976).

(c) Rice husks are currently used in Pakistan for firing brick kilns due to the lack of sufficient timber for this purpose. In the Philippines (Mindanao) there is a 25-ton per hour capacity rice dryer and milling complex (25-ton milled rice/hr) which has been using husks to operate a 1,800 kW electrical generating plant which produces 412,000 kwh per month. The adjacent town is supplied with an electrical surplus of 60,000 kwh per month which results in revenue of about US$ 2,000 per month.

In Thailand, another example of husks being used as an energy source is in the firing of a locally made boiler and piston steam engines in rice mills. The husks are only partially combusted to ensure an adequate furnace temperature. An entire rice mill can be powered by husks and there is enough surplus energy, if the 100-ton a day capacity of a mill is fully utilized, to operate a par boiling plant. The requirement for such a mill is 12 tons of husks per day.

/Before

Before the recent development of kerosene and butane gas as a fuel for domestic use in rural areas, farmers in the Republic of Korea used rice husks as a cooking fuel. Since then this activity has been discontinued, which has resulted in an increasing problem about the disposal of surplus husks.

(ii) Immediate potential uses

With the current energy crisis, there are a number of countries that are interested in quickly developing alternative energy sources. In particular, the Philippines and Thailand have embarked on a programme of a substantial scale to produce substitutes for petroleum imports from agricultural sources.

(a) Ethanol as a fuel

For many decades ethanol in the form of potable alcohol has been produced as a downstream product from the utilization of high sugar content raw materials such as molasses which is a residue in the process of producing sugar from sugarcane or sugarbeet. Recently attention has been given to the production of industrial grade alcohol from molasses as a source or raw material supply to the cosmetics, pharmaceutical, plastics and textile industries. During the past seven years, Brazil has been developing an ethanol industry based on molasses, sugarcane and cassava as a source of automative fuel to decrease her massive petroleum imports. Initially Brazil has developed some 218 alcohol plants which can produce sufficient fuel to substitute up to 20 per cent of the gasoline requirements in its transportation system in 1980. There are 123 annex type plants (distilleries attached to a raw sugar factory) and 95 autonomous type plants in production or under construction where sugarcane or cassava is the raw material input and alcohol the only output product.

In these plants and those proposed in the Philippines and Thailand, not all of the end-product potentials will be produced as shown in figure 5. The only output will be CO_2, industrial ethanol (95 per cent ethanol), stillage (spent wash), and cooling water.

/While

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While McCann (1978) predicts that stillage and other wastes such as peelings and tops of cassava could provide more than sufficient energy for process requirements through a bio-gas generator (see figure 3), there is only one reported instance of such a system being used in commercial practice. Hence, this technology needs further evaluation and development before it can be fully adopted. In the case of cassava and even sugarcane, this development is of vital importance in the energy economics of ethanol production. It will enable a greater degree of integration of ethanol production both from molasses sugarcane and upon diversification, through the addition of cassava as a raw material. Normally, as shown in Case A in figure 13, all of the bagasse (13 per cent fibre) is needed to reach thermal balance in a raw sugar-mill (4,000 t/d). By modifying the boiling house as shown in Case B, there is a bagasse surplus of 43 per cent which is available for additional distillery requirements.

In the Philippines, the approach to adopting the Brazillian model has evolved a very objective policy which aims at an even more efficient utilization of available energy from the available plant residues. This design proposes to take into account the existing and potentially available surplus energy generated in a sugarcane factory. Therefore, it is proposed to set up a twin line ethanol factory in which 75 per cent of the production will be from sugarcane and 25 per cent from cassava. This approach takes advantage of the higher recovery rate from cassava and provides the necessary energy available from the sugarcane without sacrificing the energy balance. Table 8 gives the comparative recovery rate of ethanol for various raw materials.

/Figure 13.

Figure 13

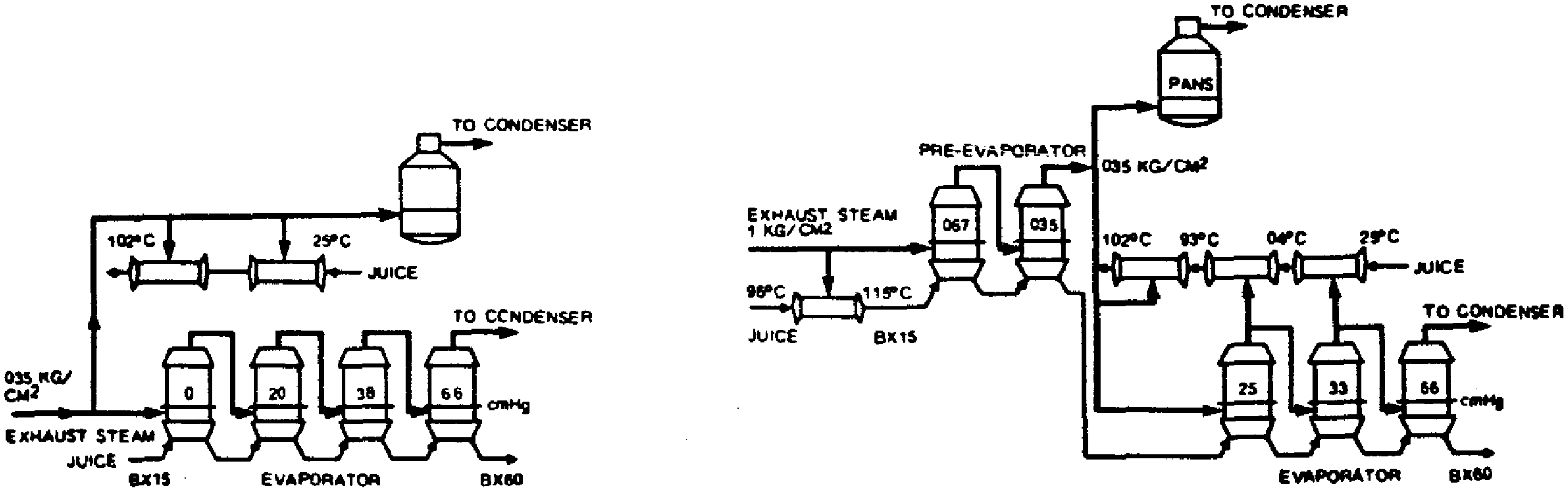
RE-ARRANGEMENT OF BOILING HOUSE LEADS TO EXHAUST STEAM ECONOMY

CASE A

EXHAUST STEAM CONSUMPTION 52 % CANE

CASE B

EXHAUST STEAM CONSUMPTION 34 % CANE



Source: OECD, Molasses and Industrial Alcohol (1978)

Table 8 Ethanol Production Ratios

Crop/residue	Litres/ton raw material	Percentage Recovery (approx)
Molasses	270.0	24.5
Sugarcane	88.0	7.9
Cassava	180.0	16.2
Sorghum	88.0	7.9

When considering the conversion of plant materials such as cassava into ethanol, there is an additional preparation process prior to fermentation, the first stage in processing molasses to ethanol. After the standard preparation and disintegration of the tubers, the slurry is adjusted for pH by the addition of sulphuric or hydrochloric acid. The slurry then undergoes an acid hydrolysis to reduce the starch and cellulose to fermentable sugars. The alternative, and much more efficient method of saccarification (hydrolysis), is the enzymatic system using a 'celluloses' to reduce the cabohydrates to glucose. However, unless it is possible to obtain a cheap source of enzymes, the acid hydrolysis technique is preferred.

It should be noted that with the adoption of an alcohol fuel programme, a second generation pollution problem will occur with the discharge of stillage and perhaps through the handling of large volumes of cooling water.

Moreover, it is essential to conserve water through recycling it as a raw material input especially where water is in short supply. Finally, stillage should be further used through a bio-gas generator (a future development) to provide bio-gas as an energy source for the distillery particularly as the cost of petroleum fuels is becoming prohibitive and uncertain in supply.

/With

With the current and possible future price of gasoline, the 'alcogas' or 'gasohol' projects, whether of the annex or autonomous types, are and will be one of the major development thrusts in utilizing residues of energy potential in this region. For further information on industrial and fuel alcohols reference should be made to Alcohol Fuels (1978) and Molasses and Industrial Alcohol (1976).

Table 9 shows the general characteristics of energy crops which could be a renewable resource for fuel alcohol production.

/Table 9

Table 9. Characteristics of Energy Crops

	Sugar Cane	Sugar Beet	Sweet Sorghum	Cassava	Corn	Wheat	Eucalyptus
<u>Agricultural</u>							
Annual Nitrogen requir.(KgN/ha)	200	170	70	90	low	low	5.4
Water requir.(m/y)	1.6	0.6	0.5	1.2	0.5	0.5	moderate
Need for irrigation (a)	yes	yes	yes	yes	no	no	no
Harvesting mechanisation	yes	yes	yes	difficulties	yes	yes	yes
Labour requir.	low	low	low		low	low	low
Length of growing season (days)	annual	annual	112	210-300	annual	annual	8 years
Length of harvesting season (days)	210	180	180	273	can be stored		365
Raw material storage	no	no	no	Starch only	yes	yes	yes
Multiple cropping	no	no	yes	no	no	no	continuous
Sucrose/starch/wood yield (wet)	17.0%	15.0%	15.4%	25%	60%	56%	16 te/ha p.a.
Theor. Klitres EtOH/ha p.a. - world avg.	4.1	4.1		2.3	0.5	1.0	2.3(b)
- world high	16.3		8.9	17.8			

Processing							
Ease of sugar/ starch extraction	v.easy	mod.easy	v.easy	mod.easy	mod. diffic.	mod. diffic.	n.a.
Ease of conversation to fermentables	unnec.	unnec.	unnec.	mod. easy	mod. easy	mod. easy	v.difficult
Fuel requirements	excess avalbl	high(c)	excess avalbl	high(c)	high(d)	high9d)	v.high(e)
Valuable by-produces	no(f)	yes	no(f)	yes	yes	yes	no(f)
Est. fixed capital per litre daily capacity	$56			$37	$47 (depreciated)		v.high
Overall							
Energy ratio (output/input)	>1	(g)	>1	<1(h)	(g)	(g)	(g)

(a) In order to obtain high yield
(b) If wood is not used as fuel
(c) Unless tops are used
(d) Decrease if tops, stalks, husks are used
(e) Reduce greatly if wood used as fuel
(f) In a large plant, CO_2 may become a useful byproduct
(g) Unless tops, etc. are used effectively will be < 1
(h) Finely balanced

Source: C.P. Shechan (1976)

(b) Charcoal, producer gas and condensates

While charcoal production is a very old industry in many parts of the world, there has been developments in recent years to design and build kilns which are efficient in converting ligno-cellulosic residues into good quality charcoal and possibly recovering the by-products of distillation.

Modern kilns have better control of combustion and therefore result in higher recovery rates, viz., the Beehive Kiln. This kiln type (with reserve draft) as described by Estudillo (1976), yields 27 per cent charcoal from tree trunks in 20-24 hours. Also Charcoal Industries (Conway, South Carolina) has successfully developed a method of continuously carbonizing sawdust. This is followed by the agglutination (briquetting) of the finally produced charcoal which in this condition is a valuable heat source. Potentially this concept can be used to convert sawdust from a coconut stem or rubber tree timber industry into a useful energy source. Also it is possible that such technology could utilize the dust residue from the coir industry in the Philippines, as proposed by Forest Products Development Commission (FORPRIDECOM). This action would be of significant value in eliminating a very important source of pollutant material which is currently of great concern as it is causing a major problem in the rivers and streams into which coir dust is washed.

Earl (1975) has evaluated the value of tropica woods as a source of charcoal and their condensates as a source of potential renewable resource energy. The potential production of such fuel is given in table 10.

It is possible that, provided sufficient quantities of residue timber of both coconuts and rubber are available, a capital intensive processing plant capable of conversion of these materials would be a viable proposition. Earl predicted in 1975 that the equivalent cost of producing charcoal as a fuel for industrial purposes would be less than that of the current cost of petroleum fuels.

/Table 10

Table 10 Specific gravity and yield of woods from a few selected trees

Species	Specific Gravity (air-dry)	Country	Remarks
Alnus rubra	0.46	U.S.A.	Yields of 43 tonnes /ha/year in Canada. Possible use in energy plantations.
Eucalyptus saligna	0.70	E. Africa S. Africa	Yields of 40-50 tonnes /ha/year widespread plantations.
Picea sitchensis	0.46	U.K.	Yields of 12 tonnes /ha/year widespread plantations.
Maesopsis eminii	0.54	Uganda	Yields of 15 tonnes /ha/year widely planted

Specific gravity of some common fuels

Fuel	Specific gravity
Coal (bituminous)	1.1
Oil (fuel)	0.9
Paraffin	0.8
Charcoal	0.4

Source: Earl (1974)

Constraints such as consistent supplies and collection problems have probably deterred adoption of such technology. Such fuels would, however, be of interest only to processing industries which were not self-energizing, such as animal feed, cassava ethanol, rubber, rice drying and autonomous distillation plants. This application would require an extensive economic evaluation into the over-all situation regarding opportunity costs in each case.

/(iii)

(iii) Mid-term possibilities

In this category we are looking at those technologies which are at or near the pilot stage of development. It should be mentioned that there appears to be a very slim line of distinction between this and the previous category.

(a) Pyrolytic conversion

Pyrolytic technology for the conversion of agricultural wastes to energy sources such as char, fuel oil and gas has been developed by the Georgia Institute of Technology (U.S.A.). During the past five years, applied research programmes have been carried out in the Philippines and Indonesia using sawdust, rice husk, coconut shell, coconut husk and sugarcane bagasse. A feasibility study was drawn up in 1976 and an aid development project for Indonesia launched in 1978.

Pyrolytic conversion processes relatively dry, cellulosic agricultural waste, such as sawdust, rice husks, coconut shell and husks and bagasse, into char, fuel oil and gas, using a simple converter. A small locally-made converter, costing about US$ 1,000 to US$ 2,500 is estimated to give a financial return of between 15 to 20 per cent per year. The converter uses rice husks as an input, a waste material found at more than 30,000 rural rice mils in Indonesia.

Pyrolysis, or destructive distillation, is the thermal degradation of a ligno-cellulosic material into simpler compounds, and its basic principal (charcoal making) has been known for centuries. The useful products of pyrolysis are a char, an oil, and a mix of gases. In rural areas, a pyrolysis process that predominantly generates a gas, is normally of little interest because of the problem of transporting this bulky, low energy product to a potential user, unless there is an onsite use (drying). The char and oil, on the other hand, represent dense, high energy fuels which are storable and readily and economically transportable. Thus, a pyrolysis converter designed to maximize char and oil production is most desirable for converting agricultural wastes to useful energy forms or to other useful products such as charcoal filters, activated carbon, rubber processing additives, carbon elements, etc.

/The

The relative amounts of char, oil and gas produced by any pyrolytic conversion process are primarily controlled by three variables. That is, (a) the residence time of the feed in the pyrolytic reactor, (b) the temperature in the pyrolytic reactor and (c) the pressure in the pyrolytic reactor.

Most of the technically successful pyrolysis systems developed to date have involved moderate residence times and ambient pressure. Low temperature pyrolysis conversion favours char and oil production, while high temperature pyrolysis conversion favours oil and gas production.

A low temperature pyrolysis conversion, because it maximizes char and oil production, is best suited for various kinds of agricultural residues. Conveniently, low temperature pyrolysis conversion typically requires readily available materials and relatively simple technology. It is thus more rugged and can be more simply maintained than high temperature systems, a special advantage in developing countries.

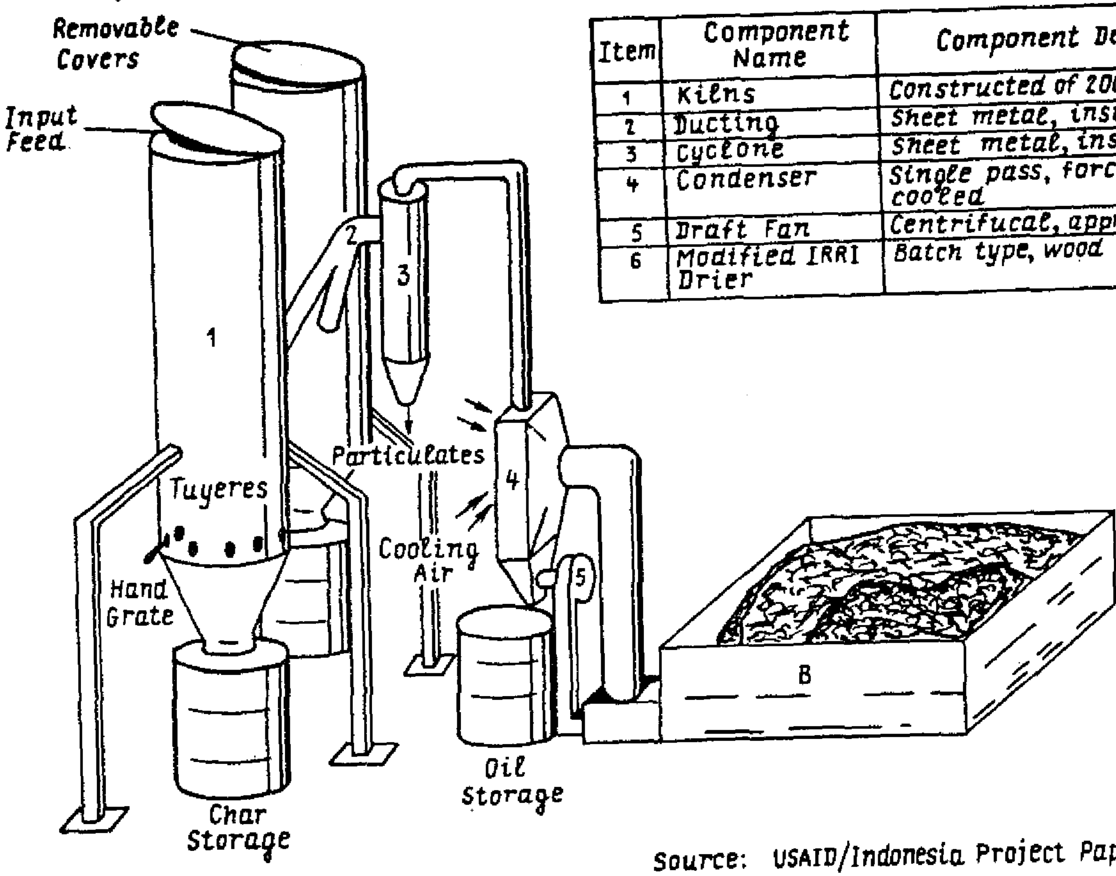
Because the pyrolytic converter must operate in areas remote from outside sources of power, the system must be self-sustaining. One simple, well understood, technically developed way to accomplish this is to provide the heat necessary to maintain the reaction rates at attractive levels through partial oxidation of a fraction of the produced char. A steady-flow, vertical, porous-bed, reactor design is mechanically and technically the simplest means to achieve this.

In order to use energy from wastes, especially in homes, some changes in habit might be necessary and the development of auxiliary equipment (such as cooking stoves and lamps) that can burn the pyrolytic oils must be made. Also, appropriate equipment to convert the char to convenient "charcoal briquettes" may be needed.

A recommended design of a pyrolytic converter is shown in figure 14 which is suitable for a typical village size rice mill or could be used as a mobile unit for coconut timber mills.

/Figure 14

Figure 14 ONE-TON-PER-DAY PYROLYTIC CONVERTOR FOR INDONESIA—MODEL 1



Item	Component Name	Component Description
1	Kilns	Constructed of 200 liter oil drums
2	Ducting	Sheet metal, insulated
3	Cyclone	Sheet metal, insulated
4	Condenser	Single pass, forced convection cooled
5	Draft Fan	Centrifucal, approximately 20 cfm
6	Modified IRRI Drier	Batch type, wood construction

Source: USAID/Indonesia Project Paper 497-0268 1978

(b) Bio-gas

Bio-gas commonly referred to as 'Marsh gas' 'Gobar gas' or in technical terms methane (CH_4) has long been a focal point for developers and followers of ancient practices. This topic has been well documented and its use at the village level is discussed in depth by Srinivasan (1977), Bhushan (1977), Muller (1975). It also has been the subject of special technical bulletins such as "Gobar Gas" published by the Appropriate Technology Development Organization of Pakistan. This publication describes a simple village level type gas generator for the conversion of animal and human wastes into a high quality energy supply. The generator also improves the quality of the discharge slurry in terms of nitrogen content thus increasing its fertilizer value. Figure 15 gives one example of a simple bio-gas generator designed for village use.

In the content of this paper, consideration must be given to bio-gas generators as a means of dealing with organic affluents, such as discharges from palm oil mills and ethanol factories. With regard to such residues Stout (1977) has defined anaerobic digestion techniques as a 'wet' process of converting organic wastes into a fuel and recognizes the need to match the type of system to the particular effluent concerned. Figure 16 shows the alternative processes for producing liquid or gasseous fuels from organic materials.

Recently Sime-Darby in Malaysia developed a commercial scale pilot plant to anaerobically digest palm oil mill sludge and produce bio-gas (a mixture of methane and carbon dioxide at about a 65/35 ratio). This plant is similar to the system illustrated in figure 17, except that the sludge holding system is replaced by a further aerobic or activated sludge treatment system which would further reduce the mixtures, BOD content.

The outline of a bio-gas system suitable for generating methane from palm oil effluent or stillage (ethanol plant effluent) is shown in figure 17. The provision of a heat exchanger is necessary to enable critical control of the bio-gas generator's temperature. If the system is mesophyllic, the optimum environment temperature is 35°C while for thermophyllic organisms it is 54°C.

/Figure 15

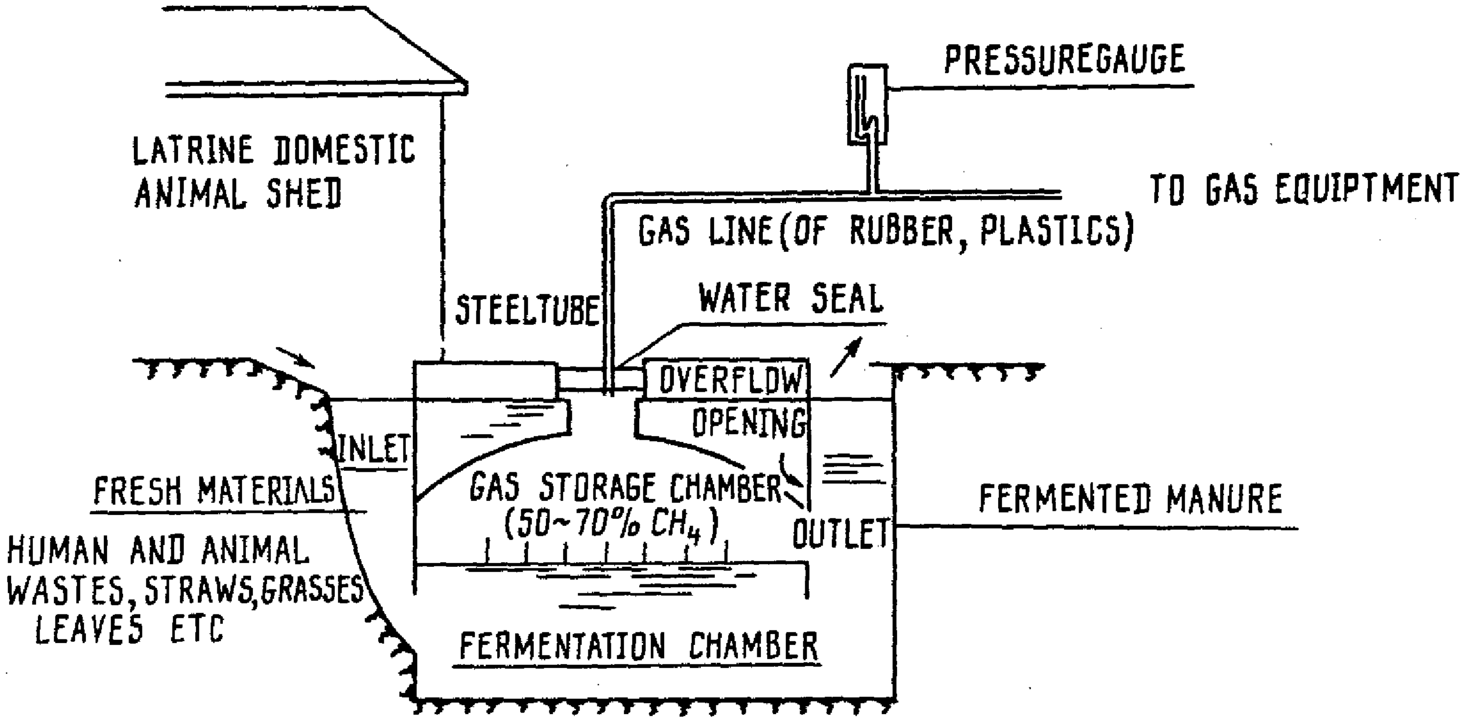


Figure 15 A biogas plant for village use.

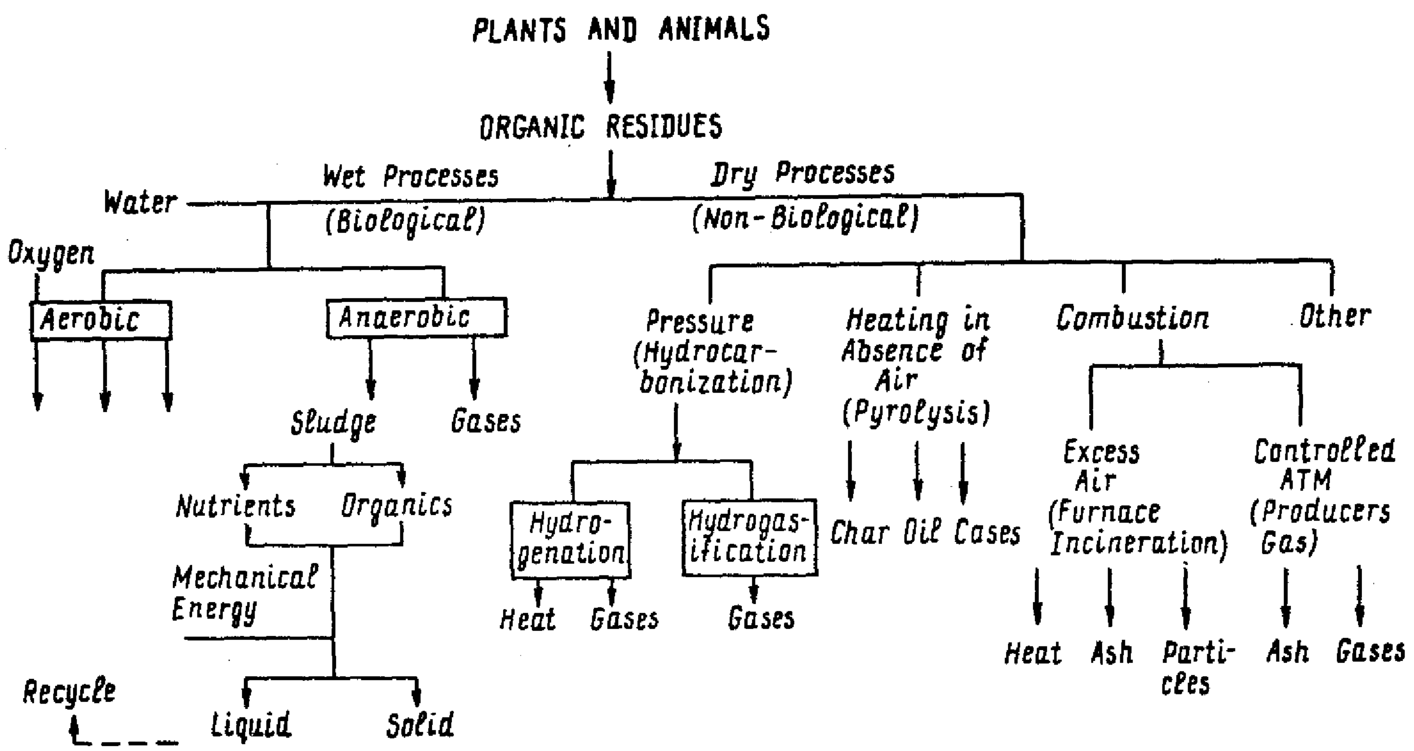


Figure 16 Process alternatives for converting organic residues to gaseous or liquid fuels

Source: Stout (1977)

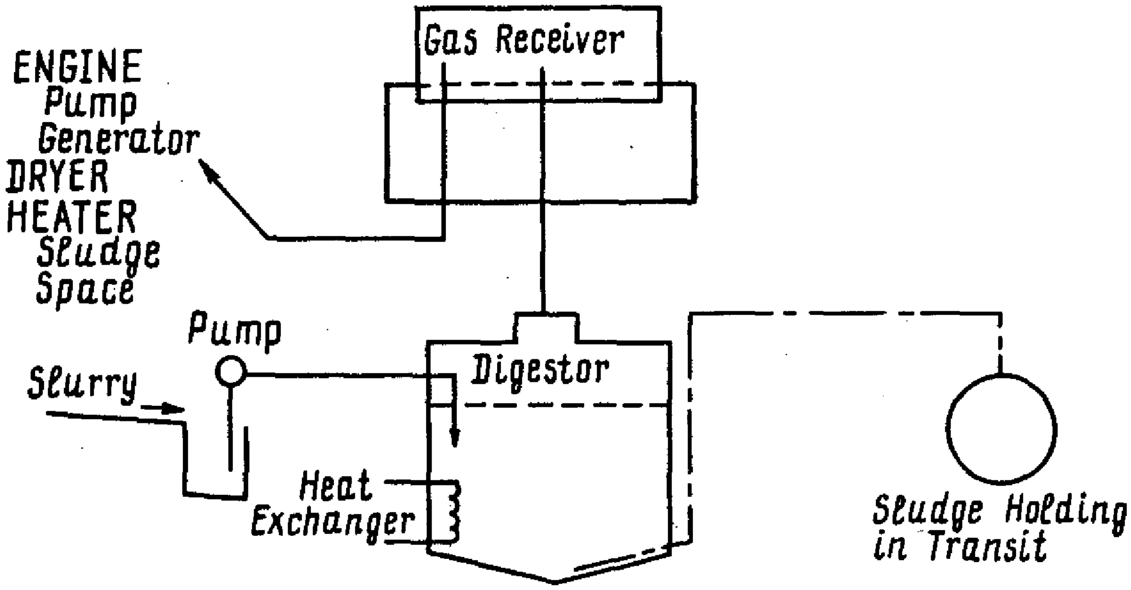


Figure 17 Schematic of a biogas generator

Source: Stout (1977)

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The Sime Darby pilot plant is designed to be thermophyllic at 60°C so as to reduce the residence time to approximately 8 days. The results obtained so far (see table 11) are very encouraging and indicate that this energy source could be a substitute for the present solid fuel (pericarp fibre), or could support an integrated second industry, such as a rubber processing plant.

Table 11 Methane Production from Palm Oil Sludge (P.O.S.)

a)	1 ton Palm Oil Sludge (94% H_2O) produces 27.83 m^3 CH_4.
b)	27.83 m^3 of CH_4 @ 5,887 Kcal per m^3 is equivalent to 163,885 Kcal/ton P.O.S.
c)	1 ton fresh fruit bunch produces 0.55 tons P.O.X.
d)	Malaysia produces 10.2 million ton ffb per year.
e)	Therefore annual production of P.O.S. is 5,750,000 tons.
f)	5,750,000 tons P.O.S. produce 16 x 10^7 m^3 methane.
g)	1 kg fuel oil @ 11,183 Kcal/kg = 1.90 m^3 methane.
h)	Therefore 1 ton P.O.S. fuel oil equivalent is 14.65 kg fuel oil.
i)	5,750,000 tons P.O.S. produce the energy equivalent to 84,222 tons of fuel oil.
j)	At US$ 170/- per ton of fuel oil, the potential fuel value of methane from P.O.S. per year in Malaysia is US$ 14.318 million.

For the utilization of methane (65 per cent CH_4 and 35 per cent CO_2), it will be necessary to modify the boilers in the case of palm oil mills and install the correct type of burners suitable for bio-gas. Where petroleum fired package type boilers are currently in use, they will have to be replaced with the correct design of boiler. Other applications of the use of methane would be to fire rubber driers, power gas engines to generate electricity, and provide energy for drying

/animal

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animal feed in processing plants. It is necessary to utilize methane at its site of production due to its incompressability and the fact that it cannot be liquified, thereby making it easily transported like butane.

For both palm oil sludge and the stillages from ethanol plants using molasses, sugarcane or cassava, it is necessary to carry out adaptation trials to determine the correct environment for bio-gas generation so as to maximize CH_4 production at an economical cost.

(iv) Future development

There is a need to continue investigations into methods of improving the carbonization of ligno-cellulosic residues into charcoal, char oil and gases. Work hould also be done on the recovery of other distillates from ligno-cellulosic carbonization as has been shown possible by Earl (1975), as presented in table 12.

Table 12 Average Products Available from Tropical Woods

Yields per 1,000 kilograms of dry wood		
Charcoal	300	kg
Gas (calorific value approximately 2,500 Kcal/m^3)	140	m^3
Methyl alcohol	14	litres
Acetic acid	53	litres
Esters (mainly methyl acetate and ethyl formate)	8	litres
Acetone	3	litres
Wood oil and light tar	76	litres
Creosote oil	12	litres
Pitch	30	kg

Source : Earl (1975)

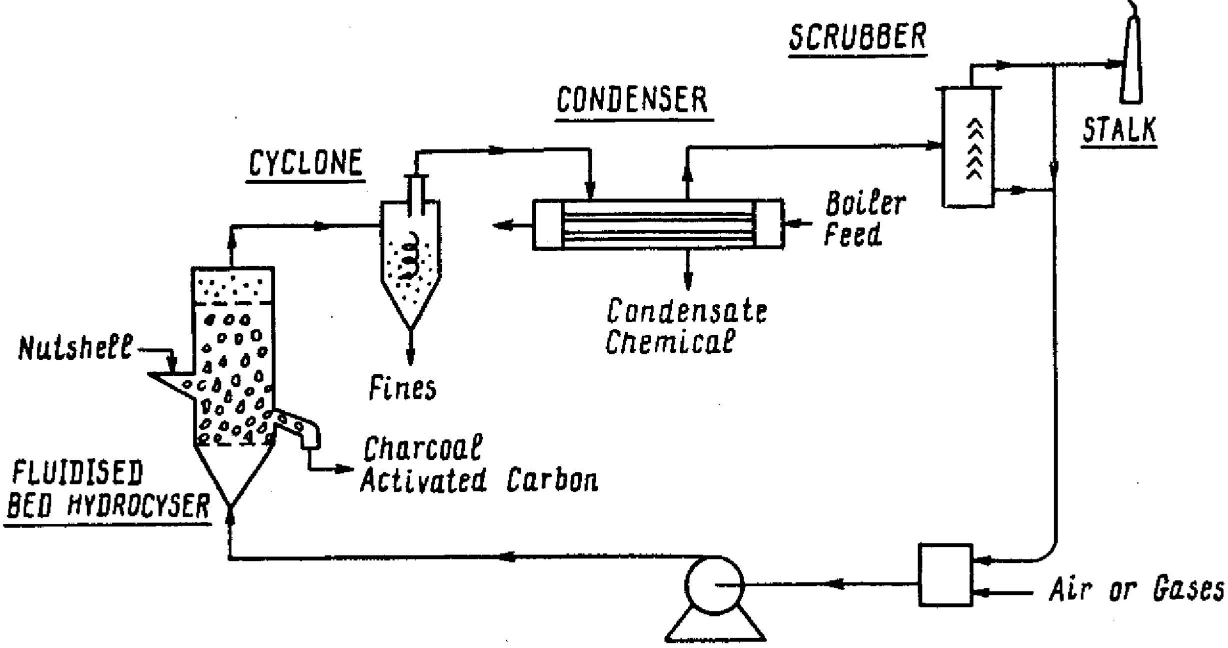
Finally, work is necessary to improve the pyrolytic conversion system for rice husk, coconut husk, coconut shell, coconut stem, rubber timber, bagasse, palm kernel shell and fibre and other suitable raw materials.

/Sutanto

Sutanto (1979) has suggested a further development programme which aims at improving the recovery of energy from palm oil mills by carbonizing the kernel shell as shown in figure 18. The conversion of empty bunches into briquettes can serve as a source of energy for firing a steam boiler which would drive a turbo alternator for electrical supply and provide low pressure steam for further use in processing various crops. Figure 19 shows the proposed arrangement for such an installation. Coupled with these developments, there is also great scope for improving the efficiency of energy utilization in both palm oil and sugarcane factories. If these developments can be achieved then there will be a considerable quantity of low cost energy available for downstream processing. It would also serve as a cheap energy source for the integration of other processing industries thus diversifying the industry's operation. An additional spin off would also be the availability of cheap electiicity for domestic and secondary commercial purposes, thus lessening the impact of inflation, particularly to rural areas.

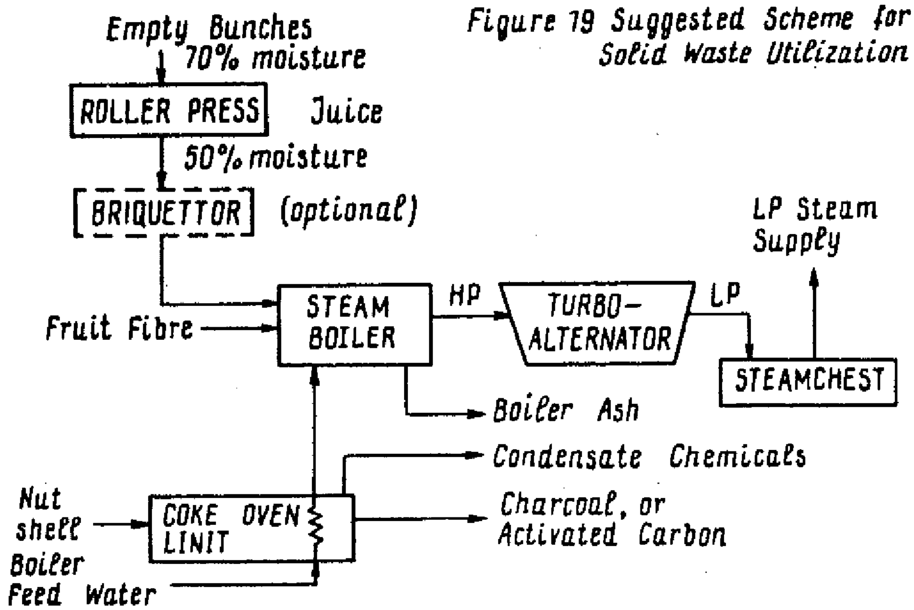
/Figure 18

Figure 18 Gas Blower Scheme for Charcoal/Activated-C Manufacture



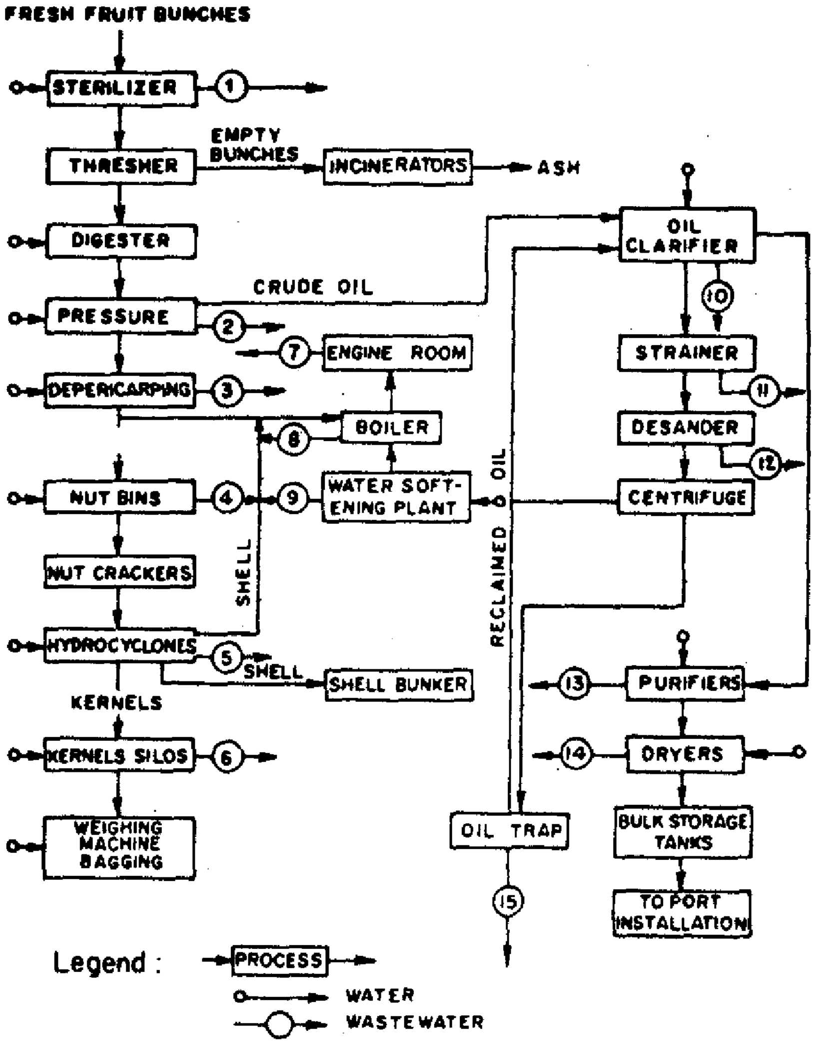
Source: Sutanto (1979)

Figure 19 Suggested Scheme for Solid Waste Utilization



Source: Sutanto (1979)

Figure 20 General Process and Wastewater Flow Diagram of a Plan Oil Mill



(1) *Sterilizer's condensate, cleansing of sterilizers and floor washing*
(2) *Floor washing*
(3) *Steam condensate*
(4) *Steam condensate*
(5) *Hydrocyclone discharge*
(6) *Steam condensate*
(7) *Turbine cooling water and steam condensate*
(8) *Boiler blowdown*
(9) *Overflow and backwash water of the water softening plant*
(10) *Floor washing of the oil room*
(11), (12), (13) *Wastewaters discharged from various units in the oil room*
(14) *Overflow from the vacuum dryers*
(15) *Oil trap discharge*

a. Food and Animal Feed as an End Use

(i) Current Uses

Both human and animal food has been derived from crops and agro-industrial residues for many centuries, such as the production of mushrooms from rice straw and the manufacture of potable alcohol and sugary syrups from molasses. Where animals are concerned in Pakistan, India, Indonesia, and to a lesser extent in the Philippines, Thailand and Malaysia the traditional practice has been to feed such animals on crop residues such as rice straw, maize stalks and cobs, sugarcane tops and cassava leaves (swine production only). In Pakistan it is estimated that 10% of the sugarcane production is used as cattle feed for draft and milk animals. Table 13 presents the most recent statistics available on the relative importance of the various categories of animal for the ASEAN countries. It therefore indicates the potential animal feed market in these countries.

There has been extensive development of the use of residues of rice, maize, sugarcane, coconut and oil palm over the past two decades. The by-products in current use has been well documented throughout the agricultural world, and can be summarised for the above five crops as follows (taken from Bol Gohl, 1975; Devendra, 1978; Hutagalung, 1978) :-

Rice Bran

Rice bran is the most important of the by-products of rice and is a good source of B-vitamins and is fairly palatable to farm animals. The bran fraction contains from 14 to 18 per cent oil. The oil can be extracted and the defatted bran is stable with respect to rancidity, which is a problem in the storage of unextracted rice bran. The rancidity is caused by a lipolytic enzyme present in the bran that becomes active when bran is separated from the rice, causing the free fatty acid content of the oil in the bran to increase rapidly. The free fatty acid content of bran from parboiled rice is below 3 per cent. Apart

/from

Table 13 Livestock population in the Asean countries (x 1000)1/

Country	Human	Buffaloes	Cattle	Goats	Sheep	Pigs	Poultry
Indonesia (1973	133,625	2,870	6,682	7,468	3,207	4,048	113,579 2/
Malaysia (1975)	10,100	213	386	329	45.5	1,168	7,622
Philippines (1973)	42,243	4,937	2,099	1,250	29	8,600	52,000 3/
Singapore (1975)	2,206	3	8	2	-	750	13,100 4/
Thailand (1975)	42.200	5,561	52	13	13	4,600	63,000 5/

1/ Source : Mahendranathan (1976); Statistical Digest 1974 (1976)

2/ Chickens: 99,769; ducks: 13,810

3/ Chickens: 50,000; ducks: 2,000

4/ Chickens: 6,900; ducks: 1,500; quails: 300

5/ Chickens: 53,000; ducks: 7,000

Source: Hutagalung (1977)

from extracting the oil, the rancidity process can be delayed by heating or drying immediately after milling. Heating to 100°C for 4 or 5 minutes with live steam is sufficient to retard the development of free fatty acids. The rice bran can also be heated dry if spread out on trays at 200°C for 10 minutes. Alternatively, the moisture content can be reduced to below 4 per cent with the same effect. Most chemical inhibitors are ineffective. The oil has a marked softening effect on the body fat and on the butter fat of milk. Provided attention is given to the oil content, rice rice brans is a valuable feed for all classes of livestock. The maximum amount that is advisable to include in cattle feeds is about 40 per cent of the total ration. For pigs, rice bran should not exceed 30 to 40 per cent of the total ration to avoid soft pork. In the final weeks of fattening lower levels of rice bran must be used. Up to 25 per cent can be included in rations for poultry and double that amount has successfully been used in experiments.

<u>Rice polishings</u>

The storage problems for rice bran applies also to polishings. Polishings have a wider use than rice bran because of their lower fibre content and can be used in poultry and pig rations. They should be included only in small amounts for piglets as otherwise they may cause scours. As with rice bran, polishings should be limited during the final weeks of the fattening period to avoid oily carcasses. Up to 5 kg per day have been used for dairy cows without any harmful effects or changes in production.

/Rice mill feed

Rice mill feed

This is a mixture of all the by-products obtained in the milling of rice. It contains approximately 60 per cent hulls, 35 per cent bran and 5 per cent polishings. The offal obtained from one-stage mills is of similar composition and is often erroneously called rice bran. Production of rice mill feed in multi-stage mills is somewhat cheaper than producing the ingredients separately. The suitability of rice mill feed in animal feeds has been well established. In countries where the use of rice hulls as animal feed is legally allowed, up to 75 per cent of the hay can be replaced by rice mill feed with good results.

Maize-and-cob meal (ground ear-maized)

This is the entire maize ear, including the cobs which form about 20 per cent of the weight. If the entire maize ear including the husks is ground, the product is called ground snapped maize. Maize-and-cob meal is valuable for fully grown ruminants and there is practically no difference in performance of feedlot animals receiving maize. Maize-on-cob meal is usually preferred to shelled maize as it is less likely to form a doughy mass in the stomach. Its higher fibre content restricts the use of maize and cob meal in diets for poultry. Pigs can tolerate 20 to 25 per cent in the diet depending on the age. The meal should be well dried as otherwise it is likely to get mouldy in a hot climate.

Maize gluten meal

The amino-acid composition of this by-product is unbalanced but maize gluten meal gives good results in pigs and poultry when mixed with soyabean meal or meatmeal. It is not very palatable and is mostly used for cattle.

/Maize

Maize germ oil meal

This product is a valuable feed for all farm animals except pigs. Meal with a high content of fat is likely to cause soft backfat when fed in large quantities. It should not be used as the only source of protein for poultry. Maximum recommended amounts for cattle are 2 kg per day and 0.5 kg per day for pigs.

Coconut

The residue obtained from copra processing is known as coconut (oil) meal (or cake) copra meal or poonac. Depending on the milling equipment the product is marketed in various grades with oil residue ranging from 1 to 22 per cent. Hydraulic press residue in usually marketed in flat round cakes but the other grades are marketed in dark coloured lumps. The product sold as sediment meal however, is quite distinct, and is actually a product recovered from the filter pads of the oil straining presses. On the average, 1,000 nuts will produce about 180 kg of copra. Processing of this copra yields about 110 kg oil and 55 kg meal, the remainder being evaporated moisture and unavoidable losses. The fibrous coat (husk) has no feeding value. The dust from processing the husks into fibre (coir dust) has been suggested as a carrier for molasses.

Coconut meal

When feeding coconut cake or meal it is important that it is not old and has thus become rancid as this will cause diarrhoea. As it swells considerably in water it should preferably be moistened before being fed in large amounts. Coconut meal should be introduced slowly into the ration, to acquire a liking by animals.

/It

It has an effect on the butterfat of the milk which tends to be hard and to get a pleasant flavour. The maximum amount to be fed safely to dairy cows is between 1.5 to 2 kg daily. Larger quantities may result in tallowy butter. Beef cattle can consume much more without having carcass quality impaired. Coconut meal is rather rich in fibre and this restricts its inclusion in pig diets. Depending on the other ingredients up to 25 per cent may be included in the diet of pigs. In areas where coconut meal is abundant and if one is prepared to accept a lower efficiency of feed conversion, up to 50 per cent can be included. It produces a firm fat in pigs.

Coconut meal is used very little in poultry retions because of difficulties in formulating a ration balanced with respect to amino-acids and sufficiently low in fibre and high in energy. The amino-acids lyśine creates special problems as much of this is apparently destroyed in screw-press meal. Rations for poultry with up to 40 per cent coconut meal have however been formulated and tested. In these the energy content is increased by the addition of coconut oil and the amino-acids balanced by addition of methionsine and lysine, or fish meal. Mouldy copra produces coconut meal unsuitable for inclusion in poultry diets.

Paring meal

Paring meal represents the outside of the shelled coconut which is trimmed off in the preparation of shredded coconut for human consumption. It has a protein of higher biological value than coconut meal as it is not heat processed.

/Oil palm

Oil palm

Utilization: Palm kernel cake, even with a comparatively high oil content, is dry and gritty and is not readily accepted by all types of stock.

Solvent-extracted meal is unpalatable and therefore has to be mixed with well-like feeds, like molasses, and fed in gradually increasing proportions. It is, however, a safe and wholesome material and if reasonable care is taken in the arrangement of the feeding it is eaten readily.

It is largely used for feeding cattle and it tends to produce a firm butter when fed to dairy cattle. It has been found satisfactory to give up to 2 or 3 kg per day to adult cattle.

Good results have been obtained from rations fed to pigs using up to 20 to 30 per cent palm kernel meal. Scouring usually results when higher proportions are used although other claims have been made where final pig fattening rations of 62.4 per cent palm kernel meal, 35.1 per cent maize and 2.5 per cent blood meal gave average weekly increase of 4.5 kg per pig. Young pigs do not always take to it and it must always be introduced in pig feeding very gradually. Palm kernel cake or meal tends to produce firm pork of good quality.

Sugarcane

Sugarcane can be used in a variety of ways in animal feeding; it can be grown for forage; the cane-juice can be used in the form of invert molasses, the leaves can be used for fodder, and the bagasse or the fine portion of the bagasse can be used as a roughage or as a carrier for molasses. Sugarcane tops is an

/important

important feed in many sugarcane growing countries, the sugar itself is used in livestock feeds when the price is low. All types of molasses are used in livestock feeding or as a substrate for the production of fodder yeast, single cell protein and monosodium glutemate.

Bagasse

An average of 60 per cent of the bagasse produced is used as a fuel in sugar mills. There are two types of bagasse; (i) fine, strong and flexible fibre that is suitable for manufacture into high grade pulp and paper, and (ii) short fibres or pithy material that yields little or no chemical pulp in paper making and will give undesirable properties to paper made from bagasse if not removed. Both types contain about 20 per cent lignin. The easiest method to separate the two fractions is to dry the bagasse and then pass it through a hammermill which loosens the pith clinging to the bagasse fibres. The material is then passed over a classifying screen or passed under suction fans which removes the pith. The finer portion is referred to as pith, bagacillo, pulp, or bagasse fines. Most studies on bagasse as a feedstuff have shown that in young ruminants it takes more energy to digest than is obtained from the bagasse by the animals. The dry matter digestibility is about 25 per cent but there is a marked variability between indiciduals in the digestion of bagasse. It contains 20 to 25 per cent total digestible nutriants. Where there is a shortage of forage, bagasse, however, may be of value.

In many such areas rations containing high proportions of concentrate feeds are used for beef cattle, while such rations cannot be used for dairy cows as the

/ration

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ration for a cow should contain not less than 14 per cent fibre on a dry matter basis. For this purpose coarsely ground bagasse has been used at levels between 10 and 20 per cent of the ration to maintain the digestive system in good working order.

Bagasse pith has been used in proportions of up to 27.5 per cent in the ration for beef cattle before production decreased markedly. Mixing the bagasse with blackstrap molasses will improve the palatability of the former. Palatability can be increased up to 55 per cent by adding molasses. It seems that older animals (over 2 years) can better utilize bagasse and it is a more satisfactory feed for these animals. The dry matter digestibility for old animals is often about 50 per cent. Bagasse is comparable to hay for mature cattle and has been used in fattening rations with good results.

Ammoniation of bagasse can depress palatability. The digestibility of the crude protein in ammoniated bagasse is about 60 per cent but the digestibility of the bagasse itself is not improved. Urea seems to be a better source of non-protein nitrogen in that it will not introduce the problems of unpalatability if mixed with molasses.

Bagasse and bagasse pith are good carriers of molasses and several mixtures of bagasse and molasses exist on the market. The use of bagasse to absorb molasses simplifies the transport and handling of molasses. In a hot, humid climate, there is a risk that a product of this kind will absorb moisture and ferment. It is essential that the moisture content of the bagasse is less than 10 per cent and that the final product is stored dry. "Camola" is one of the more common mixtures and consists of four parts of bagasse pith and 10 parts of cane molasses.

/"Molascuit"

"Molascuit" contains more molasses than any other mixture and is made by mixing pith with an excess of hot molasses after which the mixture is centrifuged. The proportion of pith to molasses in "Molascuit" is 1 to 6.25 by weight.

The feeding value of bagasse can be increased in several ways. Coarse grinding in a hammer mill (3/16 inches screen) seems to improve the digestibility. Ensiling has been attempted to break down the fibre by virtue of microbes. The most successful method tried, however, has been treatment with chemicals. The most economical method seems to be treatment with 2 per cent NaCH at ambient temperature.

Molasses

There are four principal ways of utilizing molasses :

1) In dry feeds: In addition to adding palatability, settling dust and serving as a binder, molasses can replace other more expensive carbohydrates in feeds. Its laxative effect is an added advantage in many feeds. The following levels are usually not exceeded in commercial mixed feeds: cattle 15 per cent, calves 8 per cent, sheep 8 per cent, pigs 10 per cent and poultry 5 per cent. The maximum amount of molasses to be used is often determined by the absorbability of molases by the other ingredients in the diet.

There is in general no advantage in adding molasses to poor quality roughages like straw to increase the feed intake. In most cases there will be no increased live weight gain in spite of the higher consumption. The risk of impaction is however less when molasses is added to straw.

/2)

2) <u>In silage making</u>: Molasses is quickly fermented and is, at the level of about 5 per cent, sometimes added to grass during the ensiling process to act as a preservative with its nutrient value and palatability factor as a bonus. Molasses can also be used as a scalant of silage mounds. About 5 kg molasses per square meter is usually sufficient for this purpose. If molasses is mixed into silage with low protein content it is desirable that urea be added to the molasses. Molasses may also be sprayed on hay during curing to prevent leaf-losses.

3) <u>As a carrier for urea in liquid supplements for ruminants</u>: The concentration of urea is very high in these supplements - usually around 10 per cent, but much higher concentrations are sometimes used. The daily intake of these supplements is kept low and is usually around half a kilo per day.

4) <u>At high levels, for maximum utilization of molasses</u>: In many sugarcane producing areas there is a large surplus of molasses and at the same time a scarcity of grain available for feeding. It has also been demonstrated that molasses can be used as a partial substitute for grain in beef cattle. It has also been suggested that sugarcane in many tropical countries is a more efficient producer of easily available carbohydrate than other crops. Table 14 which gives average yields per hectare and corresponding energy yield per hectare (figures from FAO <u>Production Yearbook</u> 1968-1969) illustrates this point. Sugarcane is calculated as the yield of high-test molasses and it is assumed that 100 tons of cane will give 18.2 tons of high-test molasses.

/Table 14

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Table 14 Average yields and energy yields (per ha) of maize, sorghum, cassava, and sugarcane in several countries

Country	Maize grain		Sorghum grain		Cassava tubers		Sugarcane (High-test Molasses)	
	Ton	TDN (ton)	Ton	TDN (ton)	Ton	TDN (ton)	Ton	TDN (ton)
Mexico	1.2	0.96	2.5	2.00	-	-	11.4	7.48
Jamaica	1.2	0.96	-	-	2.3	0.40	12.6	8.28
Ecaudor	0.5	0.40	-	-	7.1	1.24	12.6	8.28
Peru	1.6	1.28	1.7	1.36	11.9	2.07	26.5	17.41
India	1.0	0.80	0.5	0.40	13.5	2.35	8.7	5.72
Eteiopia	1.1	0.88	0.7	0.56	-	-	26.1	17.15
Kenya	4.3	3.44	0.8	0.64	6.7	1.17	8.5	5.58
Uganda	1.1	0.88	1.1	0.88	3.8	0.66	16.7	10.97

Source: Bol Gohl (1975)

/When feeding

When feeding large amount of molasses, molasses toxicity may occur. The symptoms are reduced body temperature, weakness and rapid breathing. Cattle usually have difficulties standing and try to lean their shoulders against the fence with their fore-legs crossed. The remedy is to take the animals off molasses feeding for a few days and immediately give them a solution rich in phosphorus and sodium. The cause of toxicity is most often due to scarcity of drinking water close to where animals are fed molasses or too rapid a switch to high molasses diets.

Molasses can also be used as a supplement for grazing cattle. Cattle on tropical pastures are often limited in their intake of digestible energy and molasses alone can often produce increased productivity. The amount of molasses given usually varies between 0.5 and 3 kg per day per head depending on the pasture.

Ammoniated molasses is now seldom used due to poor palatability. It also seems to effect the nervous system of cattle. Final molasses will cause diarrhoea in monogastric animals if fed at high levels. However, gain and feed conversion can still be acceptable in spite of the scouring.

One problem facing countries like Pakistan and India where up to 90 per cent of the power requirements are still provided by draft animals is that new grain varieties produce straw which is unpalatable to the cattle or buffalo due to a higher silica content.

Finally a feature of current usage of crop and agro-industrial residues as animal feed is that a majority of the animals, especially in the case of cattle are scattered in 1 to 5 animal units.

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However in more developed countries such as Malaysia the poultry and swine industries are very highly developed and are capable of accepting the higher cost, higher quality feeds produced by modern processing plants.

(ii) Immediate Potential and Mid-term Possibilities

In the case of animal feed development it is difficult to divide the immediate potential and mid-term possibilities.

Current potential of agricultural residue utilization in the ASEAN countries, e.g. Malaysia, has been reported (Chandapillai, 1977; Hutagalung, 1978).

The various crops and their by-product yield that could be utilized for livestock feeding (in Malaysia) are indicated in table 15.

Padi Straw

The padi areas in Malaysia have been the traditional environment for rearing cattle and buffaloes in the villages where straw, though high in fibre content, but with 35-50 per cent digestible nutrient, formed a substantial part of the diet. The feeding value of the straw could be increased by chem.cal pre-treatment and also by mixing with other feed ingredients such as molasses and urea. Devendra (1975) has reported utilization of padi straw by sheep fed with isonitrogenous diets mixed with molasses and found that 20-30 per cent padi straw in molasses-based diets were best utilized.

In the Philippines (Perez, 1975), pre-treatment of padi straw by soaking it in an aqueous solution of CaO (3 per cent) for 3 days markedly increased the digestibility of the crude fibre and Nitrogen Free Extract (NFE). In 90-day fattening trial with goats, lime-treated and untreated straw were studied, together with Leucacna Leucocephala (ipil - ipil) meal.

It was found that

/while

Table 15 Crop sources and estimated quantity of agricultural wastes available in Malaysia

Crop	Acreage ('000 ha)	Yield (ton/ha)	Metabolitable energy (ME) (M Cal/ha) 10^{x3} (D.M.)	Estimated total qty. of wastes available ('000 tons)
1. Oil palm	654	15	3.1	(Total 850)
fibre		1.3		(Surplus 240)
sludge solids		0.3-0.4	1.6	230
2. Paddy	429	4.5		
straw		2.0	3.2	800
husk		0.5	0.3	200
3. Coconut	361			
copra cake		1.0	2.5	361
4. Sugarcane	25	50.0		
leaves				
tops		10.0	3.3	250
molasses		2.0	4.5	50
bagasse		15.0	6.0	375
5. Tapioca	19	50.0		
leaves				
stem		6.0		114
refuse		20.0	1.6	380
6. Pineapple	18	16.0		
pineapple wastelage		1.0	2.5	200
7. Poultry litter				40
8. Forage crops	4			
maize				
sorghum		10.0		40
Total	1,510	-	-	3,280

Source: Chandapillai and Selvarajah (1977)

Table 16 Complete Padi Straw-Based Cattle Ration for Various Production Intensities

Item (Ingredient, %)	Low production intensity		Medium production intensity		Intensive production	
Rice straw treated	75.0	80.0	60.0	50.0	45.0	40.0
Rice bran	-	-	10.0	10.0	10.0	15.0
Palm kernel meal	14.2	9.2	13.0	13.0	25.0	22.0
Cassava root meal	-	-	6.1	14.1	6.4	9.4
Molasses	8.0	8.0	8.0	10.0	10.0	10.0
Urea	1.5	1.5	1.5	1.5	2.0	2.0
$CaCI_2$	-	-	0.3	0.3	0.4	0.4
H_3PO_4	0.3	0.3	0.1	0.1	0.2	0.2
Mineral supplement	0.5	0.5	0.5	0.5	0.5	0.5
Micro additive	0.5	0.5	0.5	0.5	0.5	0.5

Source: Muller (1976)

Table 17 Suggested Sugarcane Tops-Based Diets

Item (Ingredient, %)	Semi-intensive performance	Complete formula	Complete formula
Cane tops (dried or pelleted)	90.2	75.0	60.0
Molasses	8.0	8.0	8.0
Palm kernel meal	-	-	9.8
Cassava root meal	-	14.8	10.0
Rice bran	-	-	10.0
Urea	1.5	2.0	2.0
Mineral supplement	0.3	0.2	0.2
Vitamin A (I.U/kg)	5,000	6,000	7,000

Note: Suggested mineral supplement composition by weight); 45 per cent tricalcium phosphate, 22 limestone or oystershells, 19 per cent iodized salt, 1.0 per cent FeSO, 1.5 per cent ZnO, 0.16 per cent $CoCI_2$: 8.64 per cent carrier.

Source: Muller (1976)

while supplementation had no effect, the feeding of lime-treated straw resulted in significantly (pH 0.01) increased daily live weight gain of 192 per cent greater than that of the untreated straw with a feed efficiency of 170 per cent more than the untreated.

O'Donovan and Chen (1972) fed growing dairy heifers with rations in which chopped rice straw comprised 25 and 30 per cent of the total mixture, the remainder consisting of mainly cane molasses and urea. They found that the daily gain ranged from 0.46 to 0.82 kg., the former level reflecting the low soyabean meal content in the ration and the depressing effect of 45 per cent cane molasses.

Muller (1976) has suggested a complete padi straw-based cattle ration for various production intensities (see table 16).

Sugarcane

It is known that sugarcane produces more energy per unit area than any other tropical crop. Sugarcane crop residues are the most easily accessible, and their nutritive value is comparable to that of traditional feeds of average quality.

In sugar producing countries, feeding regimes based on sugarcane and other by-products have found greater application by farmers for routine feeding.

Recent developments in the utilization of sugarcane wastes have shown that cane residues can serve as a cheap source of feed for the ruminants, the important components being cane tops, leaves, molasses and bagasse, beside the sugar froth residue.

Preston (1974) found that derinded sugarcane, after supplementation with urea, is a more balanced feed,

/since

since it contains the fibrous pith and the cane tops which, with the addition of starch in the form of cereal grain, gives a non-additive response in terms of voluntary intake, feed efficiency and liveweight gain.

Although sugarcane leaves have higher nutritive value than leaves or bagasse, the feeding system influences to a great extent the maximum utilization of this forage. Cubing and pelleting were found to increase the digestibility of the organic matter significantly.

Experiments by the Malaysian National Livestock Development Authority's (Majuternak) showed that chopped cane tops fed as libitum as a total ration or supplemented with solid or liquid additives gave satisfactory results. Some suggested formulations are given in table 17.

The use of bagasse has not found much favour yet due to the lack of adequate technology for its utilization. Bagasse contains two portions viz, the outer rind and the inner pith. Though bagasse per se is of low quality for use as animal feed, studies have shown that steam heating at a temperature of 200°C and pressing for removal of excess water could be used for feeding cattle. (Preston, 1974)

Feeding trials in the West Indies (James, 1973) using a mixture of 'Comfith' (derinded cane) and tops fortified with urea and other feed additives fed for a period of 45-250 days to Friesian bulls varying in weight from 100-340 kg produced an average daily gain of 0.9 kg/head. When the mixture was supplemented with additional energy sources such as molasses and maize, the daily gains

/increased

increased by as much as 30 per cent. The overall feed conversion rate of the "Comfith" and cane tops mixture was reported at 4.5 kg dry matter to 0.4 kg of weight live gain. Since molasses and "Comfith" are excellent sources of available carbohydrate, they should form a good feed mixture with urea and forages. However, molasses in excess levels can cause toxic effects if the forage intake is too low and, therefore molasses must be used only if stock have access to their minimum requirement of forage of at least 1-2 kg dry matter per day.

Oil palm as a source of edible oil has emerged as a very important crop particularly in Malaysia, Indonesia, India and in the future will expand in production in Thailand, Philippines and Papua New Guinea. While palm kernel cake has been established as an economically important animal feed other components of the oil palm fruit have been investigated extensively as potential animal feed. Webb (1975, 1976) reported the successful development of the 'Censor' system of converting the highly pollutant palm oil effluent into a useful animal feed. (see Fig. 20, after Thanh, 1979). Feeding trials on swine and poultry have been carried out with successful results, from 1975 to 1978, and the 'Censor' III & IV systems shown in Fig. 8 and 9, are currently in the commercial pilot stage of development. Sutanto (1979) and Kirkaldie (1979) have successfully designed a process to recover the lost oil in palm and mill effluent by solvent extraction thus producing a potential animal food from this liquid waste. In 'Censor' III (Figure 8) there is still the need for anaerobic and aerobic treatment of the centrate after the solids have been recovered for animal feed. Sutanto (1979) listed some of the by-products that may be manufactured from palm oil mill waste as shown in table 18. Besides feed, other uses are considered in this table.

Dazell (1977) carried out a 2 year pilot scale study on the use of palm oil mill effluent as a component of a wet mix ration

/feed

Table 18 Possible Uses of Palm Oil Mill Waste

By-Product		Fruit Fibre	Empty Bunches	Nut Shell	Mill Sludge
FUEL:	Direct burning	X	X		
	Pyrolysis gas	X	X	O	
	Methane	O	O		O
FOOD/FEED:	Delignified fodder	O	O		X
	Single cell Protein				X
FIBRE:	Paper pulp	O	O		
	Paperboard	X	X		
	Coir fibre	O	X		
CHEMICALS:					
	Ethanol	O	O		
	Furfural				
	Creosote			X	
	Soluble Polymers	O	O		O
OTHERS:	Lignin products	X	X		
	Charcoal			X	
	Activated-C			X	
	Building blocks	O	O		
	Compost	O	O		X
	Fertilizers				X

Note: X - good chance

O - fair chance

feed to local Malaysian cattle and buffalo. The economics of this project are discussed by Williams (1979).

Devendra (1977) has identified potential feeds and their availability in Malaysia as follows :-

Feeds from the oil palm plant

Table 19 gives the amounts of principal products from the oil palm plant which can be exploited for animal feeding. The nature of these by-products (Devendra, 1975) and extraction rates for Palm Press Fibre (PPF), Palm Oil Sludge (POS) and Palm Kernel Cake (PKC) have been previously reported (Devendra, 1976). Palm oil (PO) and palm press fibre (PPF) are the main feed products of the fresh fruit bunches harvested; the former is the by-product of palm oil manufacture. Palm oil sludge (POS) and palm kernel cake (PKC) are two further important by-products for animal feeding.

Figure 20 demonstrates that the residues from palm oil extraction and palm nut shells constitute the major proportion of about 63 to 66 per cent. Palm oil accounts for 18-20 per cent and PPF 12 per cent. From palm kernels, the oil and PKC the by-product feed account for approximately equal proportions (45-46 per cent). Unlike palm oil however, palm kernel oil is about 80 per cent saturated.

It should be noted that values in figure 20 are approximate values and it is emphasised that these would vary with the rate of production and also be influenced by the strain of palms, climate, soil type, maturity, age of harvest and fertilization. They do reflect however, the amounts of the various products including feeding stuffs that are available.

/Availability

Table 19 Availability of Oil Palm By-Products in Malaysia (10^3)

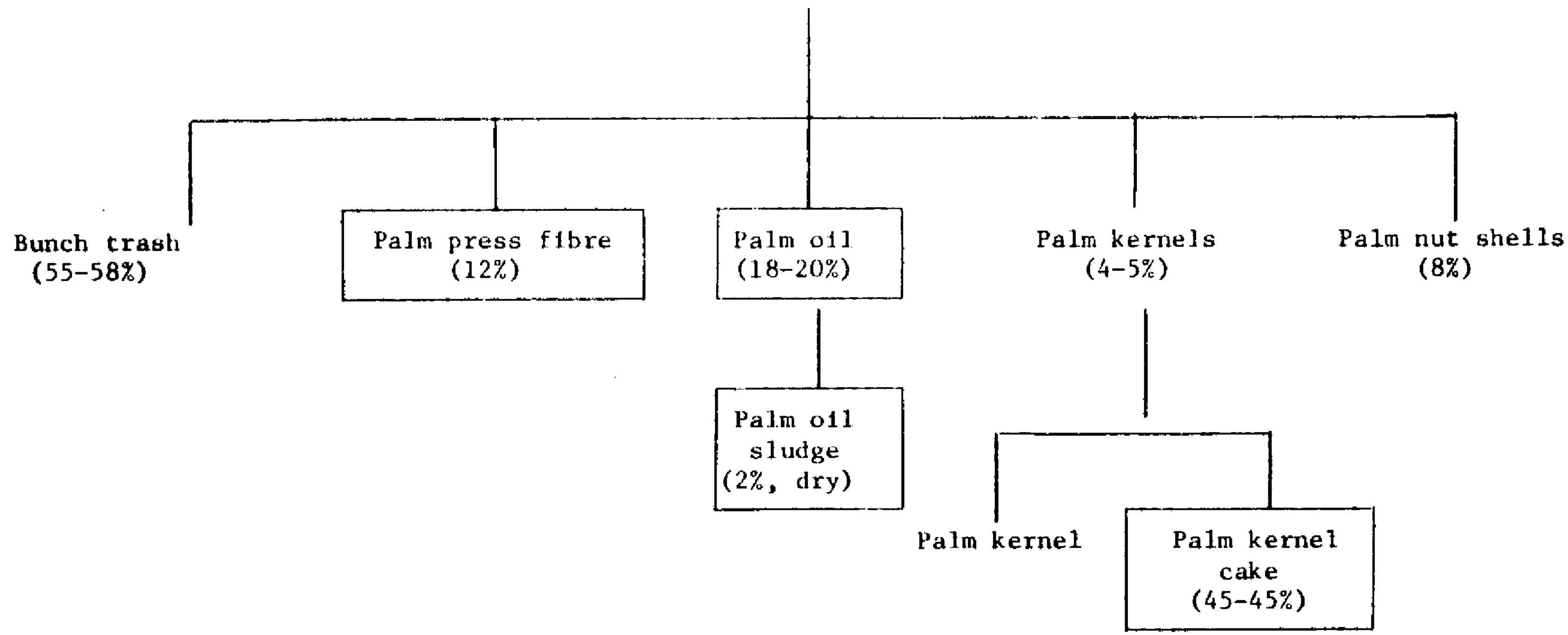
(1975-1981)

By-product by region	Year						
	1975	1976	1977	1978	1979	1980	1981
Palm press fibre							
Peninsular Malaysia	762.0	878.5	1020.8	1175.0	1340.8	1437.3	1655.0
Sabah	84.1	93.7	99.4	109.4	127.9	139.0	150.0
Sarawak	8.1	11.8	16.7	31.2	34.9	47.4	52.0
Total	854.2	984.0	1136.9	1316.6	1503.6	1623.7	1859.0
Palm oil sludge							
Peninsular Malaysia	22.7	25.1	31.3	36.9	42.5	48.4	52.0
Sabah	2.3	2.4	3.1	3.3	3.6	4.0	4.0
Sarawak	0.1	0.2	4.4	0.6	1.0	1.5	2.0
Total	25.1	27.7	34.8	40.8	47.1	53.9	59.0
Palm kernel cake							
Peninsular Malaysia	137.2	158.1	183.7	211.7	241.3	258.7	298.0
Sabah	15.1	16.9	17.9	19.7	23.0	25.0	27.0
Sarawak	1.5	2.1	3.0	5.6	6.3	8.5	9.0
Total	155.8	177.1	204.5	237.0	270.6	292.2	334.0

Calculated from the total land area under the crop and from projections (land area and production of palm oil) made by the Oil Palm Grower's Council, Malaysia.

Source: Devendra (1977)

Fig.21 Approximate Amounts of Principal Products and By-Products from the Oil Palm Plant at Maturity a/



a/ Maturity here refers to the first year in which a commercially processible crop is harvested. The data above refer to the year in which the highest production is obtainable (normally the 6th or 7th year of harvesting).

Figures in parenthesis refer to approximate proportions expressed as per cent of fresh fruit bunches.

Source: Davendra (1977)

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Availability of oil palm by-products in Malaysia

It is of interest to know how much individual by-products are available from oil palms in Malaysia. Table 19 presents this situation from 1975 and also includes the projected availability up to 1981.

The availability has been calculated using the planted area (present and projected) of mature palms with the following considerations :-

(i) First third of the area is in the younger age group which is in the first and second year of harvesting (average yield: 13.1 ton/ha).

(ii) Next one-fourth to be in the medium age group which is in the third and fourth year of harvesting (average yield: 23.6 ton/ha).

(iii) The remaining land area is completely mature palms which is in the fifth year of harvesting (average yield: 19.6 ton/ha).

It is clear that the availability of the by-products in the future will be quite substantial.

Hutagalung (1977) has identified the potentials for both oil palm mill effluent and rice residues which forms part of a very comprehensive paper evaluating the feeding potential of non-traditional feedstuff.

From the research work conducted at the University of Malaya within the last 7 years, the problem of dehydration of effluent using centrifugal solid recovery (Censor) system and other locally available materials as carriers has been overcome. This system aims to develop saleable, good quality feeding-stuffs for livestock, with a projected potential value ranging from M$ 200 to M$ 300 per ton of feed.

/(i) Oi

(i) Oil palm mill effluent (sludge)

The use of oil palm mill effluent in its fresh form as animal feed was first attempted in a primitive way in Nigeria in early 1960, but technically no data are available. In 1972, a private company in Malaysia initiated the feeding of raw effluent-based ration to cattle and buffaloes and the results of the animals' performance compared favourably with the conventional system of feeding. The results of this feedlot system have been reported (Dalzell, 1977). However, limitations is storage and transportation restrict the utilization of fresh sludge immediately after its discharge within close proximity of the oil palm processing units.

Based on the successful recovery of the oil palm sludge solids through the Censor process, various studies on the feeding value of the products in the livestock were subsequently undertaken (Webb et al, 1976). The results of feeding trials in poultry (Hutagalung et al., 1975) and in pigs (Hutagalung et al., 1977) revealed that palm oil sludge could be utilized as animal feed. Replacement of 50 per cent maize by Censor sludge in the ration of pigs and poultry was found to be satisfactory, although young animals seemed to have lower tolerance. In pigs the Censor products give a favourable response when introduced gradually. It is pertinent to note that sludge based diet tends to produce firm pork of good quality (Hutagalung et al., 1977).

Good digestibility results have also been obtained in sheep fed a combination of oil palm sludge and palm press fibre up to 40 per cent level (Devendra and Muthurajah, 1976). It was found satisfactory to

/combine

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combine the sludge with palm press fibre and palm kernel cake at levels 40, 30 and 40 per cent respectively. Continuing efforts have been made to improve the recovery and nutritive value of the sludge with various carriers, including cassava root, palm kernel, grass and poultry manure, and sugarcane tops. As a result of this study, new products, which contain higher protein than the previous Censor sludge have been developed.

One of the recent developments on sludge recovery is the breakthrough in reducing the oil content of the sludge. High oil content of sludge has been one of the constraints in the recovery of solids from oil palm mill effluent. With this new finding, a new low-oil sludge has been developed. The process involved the removal of oil from the sludge with a hexane-solvent extractor to separate the solids from the oil and liquid portion. Oil was recovered at low cost with this process. The liquid residue from this process contains high sugar and it has been found suitable as a substrate for liquid microbial fermentation, using selective non-toxic bacteria and fungi which have the delignifying, cellulolytic and protein systhesis ability. The fermented liquid and the sludge solids are combined to produce a product containing high protein and energy, low in fibre and ash, better known as vacuum filter cake (VFC) (Sutanto, Personal Communications, 1977).

(ii) Rice

Rice (Oryzae sativa L.) is the most important food crop in the rice-producing areas of Asia. In the large-scale rice-processing mills a wide veriety of by-products from the rough rice is available which

/can be

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can be utilized as animal feeds. The percentage of by-products depends on the type of rice and milling, processing rate, which are broken down into the following proportions: polished rice (50-66 per cent), broken rice (1-17 per cent), polishings (3 per cent), bran (10 per cent) and hulls (20 per cent). In particular, the bran and polishings make valuable feeding-stuffs as well as the broken seeds or broken rice.

The rice grains in their hulls known as rough rice contains about 10 per cent moisture, 8.2 per cent protein, 9.2 per cent crude fibre, 1.9 per cent other extract and 6.5 per cent ash (Lim, 1967, Bienvenido et al., 1964). The rough rice has been used to substitute maize in the diets of pigs and cattle with no adverse effects (Noland and Scott, 1963). Optimal rates of inclusion are 50 per cent substitution of maize portion, and for laying hens up to 30 per cent of the ration.

Rice hull is a very low quality roughage. It is generally used as poultry litter and the litter can later be fed to ruminants. For feedlot cattle it can be supplemented in high-concentrate diets up to 15 per cent to stimulate appetite, to reduce incidence of liver abscesses and to serve as a filler or bulk. Ammonia-treated rice hulls have been supplemented in the diet of sheep up to 40 per cent without any problems in digestion or mastication.

Rice straw is a fair quality roughage. The straw is usually combined with rice bran and the mixture is low in protein, calcium and phosphorus. The present recommendation is to use rice straw plus molasses and copra meal or urea as a diet for lactating cattle,

/buffaloes

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buffaloes and for draught bullocks. Excessive feeding of rice straw should be avoided as it contains oxalic acid which will bind the calcium in the diet. This effect can be minimized by soaking the straw in the water or neutralizing it with weak solution of calcium carbonate or calcium hydroxide.

In addition to the foregoing, a downstream development of the rice industry involves the extraction of rice bran oil as practiced in Thailand, Philippines, India and Pakistan. The Republic of Korea has already a well established rice bran oil industry which is aimed at substituting imported edible vegetable oils. The techniques recommended by Bo Gohl (1975) for preventing rancidity in rice bran as on animal feed has been adopted in the Republic of Korea so as to enable storage and transport of the raw rice bran from various rice mills to the bran oil factory which employs the solvent extraction method for recovery of the oil. The inactivation of the lipase enzymes must take place using live steam or by using day heat over drys immediately after the milling operation. This technology is of immediate potential in developing a rice bran oil industry. Amornrat (1977) has confirmed that live steam inactivation is a practical stabilization method for rice bran in Thailand.

In Pakistan there is considerable attention being given to the development of animal feed with particular emphasis on utilization of agricultural residues Muller (1978) has developed extensive proposals for the treatment and use of all organic wastes for this purpose using a transfer of technology from experience in Europe and the U.S.A. with respect to rice, maize and sugarcane. His recommendations are summarized as follows :-

It was concluded that some 28.8 million tons of crop residues are produced in Pakistan. These contain about 1.4 million tons of crude protein, 0.5 million tons of digestible protein and 14.2 million tonnes

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of TDN. With agronomic advances and with proper harvesting technology aimed at the maximum recovery for nutrients, the benefits of utilization of crop residues can be proportionally increased in the years to come. An example of the potential is given by sugarcane from which production of sugar and crop residues has increased by more than 40 per cent in recent years while the land area used for sugarcane production has increased by some 10 per cent.

Rice

Rice is the second most important cereal crop in Pakistan and provides almost 3 million tonnes of crop residues annually which provide 1.2 million tonnes of TDN and 128,000 tonnes of crude protein. The crude protein value varies according to the level of fertilizer use and varies between 0.5 to 5.9 per cent but usually averages about 4.5 per cent. The TDN value for cattle is estimated to be 45 per cent and for sheep 4.1 per cent.

The high mineral content of rice straw seriously limits its utilization. Oxalic acid is another unwanted constituent which, when rice straw is fed in excess, can cause rumen disorders. Oxalic acid can however be eliminated by several treatments. Physical and chemical treatment increases the digestibility of rice straw from 45 to 60 per cent.

Maize

Maize generates about 1.5 million tonnes of TDN containing 52,000 tonnes of crude protein of which about 21,000 tonnes can be considered as digestible. The maize crop produces about 85 per cent stover, 9 per cent cob and 6 per cent husk. These components

/vary

vary considerably in chemical composition and nutritive value. The digestibility and protein content of maize crop residues can be considerably influenced by agronomical practices. The longer the lapse of time following the harvest the greater is the damage to the nutrient content and the digestibility of nutrients. High density planting and high temperatures and intense photosynthesis increases the yield of residues, but nitrogen fertilization does not necessarily have the same effects in high yielding varieties.

Treatment of maize crop residues increases their digestibility by 30 to 50 per cent. Maize crop residues are better utilized when ensiled or processed in the form of pellets or cubes. An example of ensiling maize crop residues with cattle manure is formulated as a system suitable for low performance ruminants.

Sugarcane crop residues are readily accessible to many farmers and are produced in such quantities that they overshadow all the classical forage species. About 4.7 million tonnes of sugarcane tops are generated from existing sugarcane production which also provide 366,000 tonnes of molasses and 11,000 tonnes of pith. When the available feed resources derived from sugarcane (mainly tops and molasses) are reclaculated in terms of nutrients, it is estimated that some 3.2 million tonnes of TDN could be derived from this crop. This quantity would provide the TDN requirements of some 1.1 million dairy animals or 1.9 million head of bagasse, pith, filter mud and molasses are tabulated in considerable details in-so-far as their chemical composition and nutritive values are concerned. The survey showed that Pakistan molasses

'is

is of high quality (above 80 Brix°, 31.7 per cent sucrose and about 20 per cent reducing sugars).

Various feeding systems (fresh, sun-dried, dehydrated, cubed palleted and ensiled sugarcane tops) are compared from in vivo and in vitro results showing that cubing and pelleting and to some extent ensiling significantly enhance the feed intake and digestibility of the organic matter of sugarcane tops. Formulations of rations for maintenance, semi-intensive and intensive feeding involving 80 per cent, 65 per cent and 40 per cent sugarcane tops respectively may offer economically viable feeding systems.

Bagasse being the main by-product is almost exclusively used as a fuel for factory boilers, but this system is already being substituted by natural gas and other fossil fuels and it is likely that this change will continue in the future. This is because material for paper manufacturing (wood pulp) is a limiting factor in the country (Pakistan) and bagasse offers an important alternative feed stock. Depithing of bagasse for pulping will generate pith which can be utilized after treatment together with molasses as an important source of nutrients for livestock. It is envisaged that commercially viable feedlots for dairy or beef cattle could be established within the premises of sugarmills as a joint venture between sugarmills, paper mills, abattoirs (Government) and meat processing plants (foreign investors and markets). It is estimated that an average size sugarmill has the capacity to generate sufficient quantities of pith and molasses, which could constitute about 80 to 85 per cent of a complete ration (calculated on dry matter basis) to support a beef feed lot of 20,000 to 30,000 animals per annum or an equivalent number of dairy

/animals.

animals. Another alternative is the conversion of these resources into marketable products in the form of pellets. Cubes or molasses blocks for local and foreign markets.

Recommended Treatment

As digestible energy is usually the first limiting nutrient in ruminant nutrition in warm climates, it is axiomatic that treatment of crop residues is directed towards liberating cellulose from the long-cellulose structure. This effect can be achieved, either by physical (mechanical), or chemical, or biological treatments.

(1) Mechanical processes are represented by fine grinding, high pressure/high temperature treatment, irradiation and compaction technologies.

(a) Fine grinding of roughage significantly increases its digestibility. Although this process do not delignify the roughage they nevertheless expose a greater surface area to the rumen micro-organisms and thus assist access of the organisms to the partly damaged machanical tissues and thus facilitate digestion.

(b) Compaction processes involve reduction of volume which assist intake of roughage but do not markedly influence the digestibility of the contained nutrients. Compaction processes involve conversion of crop residues by several mechanical means into wafers, cubes, pellets, bricketts or blocks. Such compaction systems have commercial applicability and allow maximum incorporation of straw into complete rations. Cubing of crop residues requires less energy and less binding agent than pelleting. The actual

/cost

cost of cubing straw, ranges between US$ 20 to 21 per tonne, while the cost of pelleting is higher (US$ 24 to 27 per tonne).

(2) Chemical treatments include the use of alkalis, acids, ammonia, chlorine and other chemicals.

(a) Alkali treatment is employed commercially in several techniques. The wet-alkali process uses 4 per cent NaOH solution. An alkali soaking bath is operated above 100°C with a soaking time of from 15 to 30 minutes. There are many modifications of this system which can be adjusted to farm level. Drying which usually makes the wet alkali treatment prohibitive, can be avoided by mixing the treated residue e.g. straw, with fresh acid wastes such as silage or fruit wastes and feeding directly to cattle.

The Danish system of alkali treatment is a dry process. Straw is treated with concentrated NaOH. The alkali treated straw is compacted, this generates heat and enhance the mobility and effectiveness of the NaOH. Compacting of straw reduces its volume and the final product is dry because no moisture is added in the course of the treatment. Organic matter digestibility increases from about 48.2 per cent (4 per cent NaOH) or 66.7 per cent (6 per cent NaOH). The alkali process can be significantly accelerated when combined with cubing or pelleting. The deciding factor in accessing the feasibility of this method is the cost of sodium hydroxide.

(b) Chlorine treatment uses chlorine compound such as organic chlorine, $NaClO_2$ bleach, $Ca(ClO)_2$, $KClO_3$, CI2 gas and others. These compounds being oxidizing agents reduce the lignin content considerably without loss of other soluble nutrients since no

/addition

addition of water is used. The technology is new and there is not sufficient information at the present time on applicability under field conditions. Nevertheless in the long term, this process may similarly affect the soil because of a build up of chlorides.

(c) Ammoniation processes are based on spraying straw with 2 to 5 per cent liquid ammonia under plastic sheets. After spraying, the sheets are sealed and left for the NH_3 to act for at least six weeks. In warm climates such as Pakistan the effectiveness of the ammoniation process will be increased. The treatment is simple, applicable at farm level, has no side effects on soil and does not degrade the natural protein contained in the crop residue. While alkali treatments damage or degrade most of the protein in crop residues, the ammoniation process can increase the level of crude protein by up to 8 per cent. Ammoniation increases the digestibility of organic matter to the same or similar extent to the alkali method. The cost of ammonia treatment at the farm level would be in the range of US$ 5 to 7 per tonne. More recently ammonium bicarbonate (NH_4HCO_3) has been used instead of ammonia, as the ammoniating agent together with compaction. The advantage of using NH_4HCO_3 is that temperature generated during the pelleting process ($60^{\circ}C$ without additional steam) is sufficient to break down the NH_4HCO_3 into NH_3, CO_2 and H_2O which speeds up the ammoniation process taking place in the course of pelleting. The producting of NH_4HCO_3 is possible in Pakistan because of the existance of a nitrogen systhesis industry.

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The ammoniation process is applicable to any kind of crop residue and produces reliable and consistant results, the volume or density of the crop residue (long straw, chopped, baled etc.) does not effect these results. In addition, residues with either low (not less than 5 per cent) or high (up to 40 per cent) moisture can be used with equally good results. In the case of pelleting, after ammoniation, it is however necessary to handle straw with less than 20 per cent moisture, otherwise dehydration must be added to the cost.

Increased pressure and temperature has a positive effect on the final product as it intensifies the ammoniation process. In Pakistan this would be easy to achieve from solar heat below plastic sheets which would provide a temperature much above 40^{o}C even in winter (in the course of the day's sunshine 10.00 A.M. to 5.00 P.M.) High temperature shorten the ammoniation process while low temperatures would require longer storage time. Nevertheless the longer the storage the better are the results. Higher concentrations of NH_3 enable a shortening of the storage period. An optimum economic balance is 2 per cent NH_3 for 42 days.

(d) Acid treatment of crop residues involves the use of inorganic acids (1 to 6 per cent H_2SO_4 or HCl or a combination of both). Treatment with highly concentrated acids (particularly H_2SO_4), provides chemical reduction but at greater cost and carries a subrecommendation for conditions in Pakistan.

/(3)

(3) Ensiling of crop residues does not substantially change the orginal nutritive value but markedly increases the palatability of residues. Ensiling rice straw helps to eliminate the problems of potassium oxalate. Similarly most of the glycosides and other phytotoxins are usually destroyed by the ensiling process (prussic acid in sorghum crop residues and in cassava leaves or roots, tannic acid in sorghum grain etc.).

(4) Biological processing of crop residues has recently been developed and can be divided into submerged and semisolid fermentation.

Submerged, sterile fermentation processes convert crop residues into single cell protein or other proteinacceous biomass. Thus from 100 kg of bagasse about 13 kg pure protein (26 kg yeast containing 50 per cent protein) can be produced. The process is very capital intensive and only large scale units may become profitable.

Semisolid fermentation processes have several modifications. One American method involves grinding of straw and pre-treatment either by acids or alkali. The digestibility of the fermented straw increases from 32.7 to 46.7 per cent (H_2SO_4 hydrolysis) or to 55.9 per cent (alkali hydrolysis). The improvement is not sufficiently significant to justify the high cost of investment required. The cost of fermented straw ranges between US$ 70 to 80 per tonne depending upon the method of hydrolysis used during the process. Another semisolid, but semi-sterile technique is a self-generating fermentation process which simultaneously converts livestock wastes (manures, litters, crop residues and by-products) into a fermentation

/biomass.

biomass. This system consists of a digester and the process takes only 24 to 48 hours. The digested biomass is other balanced with other ingredients to form a complete ration.

Non-agricultural uses of crop residues are briefly mentioned when consideration is given to systems of crop residues utilization other than for feeding. Crop residues can thus be converted into carbon or into fuel, as their carbon content is about 40 per cent, which is approximately the same as in common lignite fuels.

More sophisticated methods can be used to convert crop residue into chemicals such as hydrogen, methanol, methane, ammonia, nitric acid, urea and many others. Although technically feasible, their economic viability could only be established when large volumes of crop residues are readily available from monocultural farming systems to meet the logistic requirements and economics of scale necessary.

Some crop residues rich in pentosans can be converted into the chemical furfural, which is used for numerous industrial processes. Apart of the main product the process also yields methanol, acetic acid and furfural waste. The latter can be used as forage substitute. An example of an economically viable unit processing 20,000 tonnes of crop residues would generate (apar, furfural and other chemicals) about 15,000 tonnes of furfural wastes which can be utilized as forage substitute for 2,000 - 3,000 head of beef cattle or 1,500 - 1,800 dairy animals.

Rice hulls, apart their conversion into fuel, can be processed into silicon tetrachloride ($SiCl_4$). It is claimed that commercial application of this process

/can be

can be economically attractive when 50,000 tonnes of rice hulls are processed annually giving nearly quantitative yields of 10,000 tonnes of $SiCl_4$.

In Pakistan sugarcane bagasse is already used as feedstock for pulp manufacture. In view of the fact that future requirements for paper manufacturing will necessitate greater exploitation of sugarcane bagasse it is envisaged that, within a decade most of the available bagasse will be utilized for this purpose. This will however generate increasing quantities of a valuable by-product derived from the depithing process. This pith if efficiently integrated may have a great impact on livestock development of the country.

Fig. 22 shows the schematic layout for the alkaline treatment of cellulosic wastes as recommended by Muller (1978). However care should be taken to carry out pilot trials and evaluate the economic viability of adapting such technology.

Other possibilities of technology transfer is to use such fibrous wastes as oil palm pericarp fibre for the production of mushrooms. Comprehensive research and pilot scale trials for economic evaluation have been carried out by Graham (1976) at the University of Malaya for the production of padi mushroom.

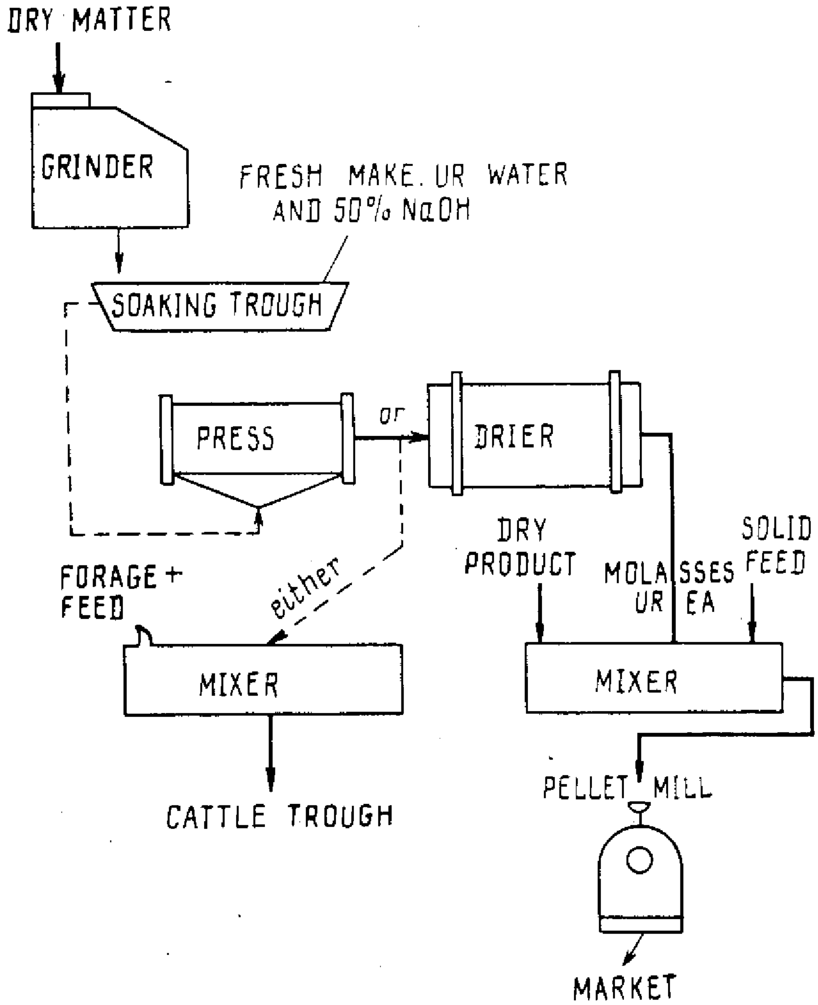
In the Philippines the sugarcane industry is developing an integrated animal production industry as a means of utilizing useful by-products and therefore provides the opportunity of developing a fully integrated recycling system for animal and plant farming which is illustrated by Fig. 23.

(iv) Future development

There are several prospects for future development of foodstuff from residues which are both primary and tertiary in origin.

/While

Figure 22 Flow Diagram of Continuous Alkali Soaking Process



Source: Müller (1978)

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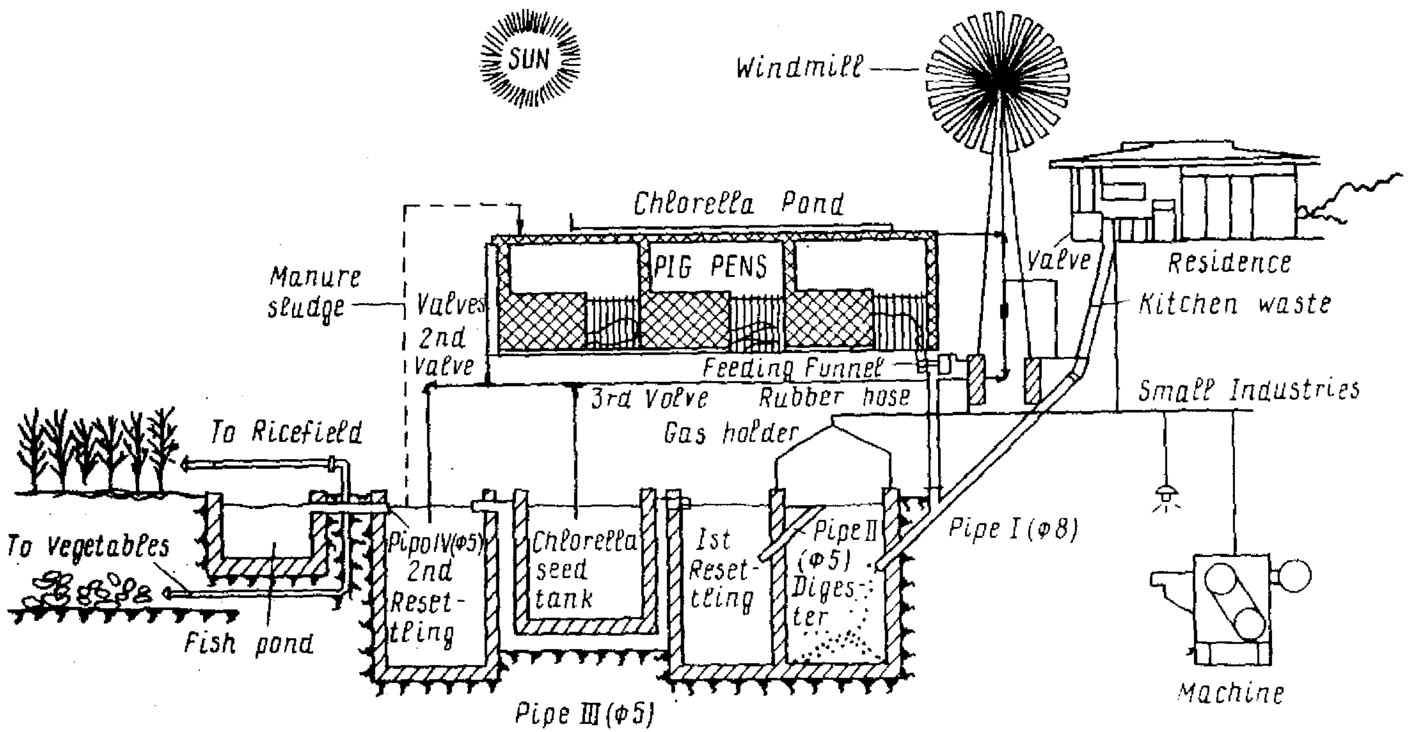

Figure 23 Recycling system in integrated animal and plant farming

Source: Eusebio (1975)

While there has been much interest in single cell protein (SCP), a protein produced from micro-organisms, there has been virtually no technology developed which is commercially practical particularly for a developing country. Production of SCP has been found to be very expensive even from cheap raw materials, as expensive equipment and sophisticated technology has to be used to prevent contamination with unwanted toxic micro-organisms, and the resultant product is lower in nutritive value than the chemical analysis indicates. Therefore further research and development in this field using waste effluents as a substrate should be continued with an aim to utilize it in more developed countries of the ESCAP region such as Malaysia, Singapore, Philippines and Thailand.

Further development of solvent extraction of oil from fibrous wastes in the oil palm industry is recommended. The development should be directed towards recovering edible oils and improving the quality of the fibre for other uses such as paper manufacture or the production of furfural.

Other research fields should consider the recovery of residues for feed by drying, packaging and transporting them to suitable locations for consumption. This will involve studies into ways and means of economically concentrating dilute liquids and upgrading the quality of certain wastes such as coconut water as a potential human food.

c. Fertilizer As An End Use

It is a well established and proven practice that crops residues and factory wastes with a fertilizer potential should be, if possible, returned to the soil on which the crop was grown so as to conserve the soil structure, water retention capacity and nutrient availability.

(i) Current Uses

In countries such as Pakistan, Thailand, Philippines, Indonesia, and parts of Malaysia crop residues that are not utilized as animal feed or as fuel are either mulched back into the soil or burnt,

/thereby

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thereby returning some of the nutrients removed by the crop plants. While there is a general tendency to burn sugarcane prior to harvest (a protection against snakes and rodents) it is the practice in dry areas such as the Sind province in Pakistan and formally in Fiji to cut the crop green. This practice enables the crop residue to be returned and mulched into the soil as a means of maintaining a good organic matter level which assists in water conservation.

For many years since the development of the modern sugarcane mill the filter mud has been returned to the fields because it contains much phosphoric acid and some nitrogen. In earlier days the molasses was also used as it contains much potash. In modern times, however, molasses only returns to the soil via a distillery if there is one attached to the sugarmill. Distilleries in Brazil and even in Thailand return the stillage containing the potash salt to the field through irrigiation waters after suitable effluent treatment techniques.

Oil palm bunch ash (produced by the incineration of empty bunch stalk at the palm oil mill) has been applied for a long time in Malaysia at a rate of 8-9 t/ha as a biennial application. This has given very good response particularly an acid sulphate soils. This residue is particularly rich in potash (40% K_2O). It is very alkaline and hygroscopic and hence must be handled with care. To avoid damage to the feeding roots it should be applied regularly in a broad band at the edge of the weeding circle. On most estates oil palm bunch ash is applied every 3-4 years so to avoid any marked effect on soil.

(ii) Immediate potential

A paper manufacture company (Siam Kraft Co., Ltd.) in Thailand uses bagasse as a major input for the manufacture of industrial papers and card-board for containers and packaging of cement and other consumer products (supermarket packaging). From the process of utilizing bagasse along with recycled paper and imported pinewood pulp from "Sweden and Canada two types of liquid effluent are produced: black liquor and discharge liquid. After recovery of the chemicals used in pulp digestion, the black liquor is anaerobically digested for a period of 6 days

/after

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after which it is blended with the discharge liquid from the paper making plant and put through a two stage aerobic pond system. The resulting effluent has been reduced to a minimum BOD and the dissolved salts have good fertilizer value. The treated effluent is capable of increasing the yields of rice and sugarcane by more than 50 per cent and it is acceptable to the local irrigation authority.

Another practice which could be transferred in the sugar industry, is to anaerobically and aerobically treat liquid effluent from sugar mills and ethanol distillaries then irrigate the resulting discharge on to adjacent cane or other crop areas. This is currently being practiced in Brazil and has been tried on a commercial scale in Thailand.

(iii) <u>Midterm Possibilities</u>

Several long term studies have been carried out on the effective use of rubber factory effluent by the Rubber Research Institute of Malaysia (RRIM) as a fertilizer on a number of crops. The quantity of effluent from rubber production is quite substantial (22 kg per kg of rubber produced). Due to the use of ammonia in the collection and storage of latex the fertilizer value is quite evident as can be seen from tables 20 and 21.

<u>Fodder Production</u>

John (1978) has reported its use as a fertilizer for fodder production from grasses and legumes :

> Tan, <u>et al</u>. (1975) applied a mixture of effluent from latex concentrate, cup lump and skin processing plants to Napier grass (Pennisetum purpureum) and star grass (Cynodon plectostachyus). The total dry matter and crude protein obtained were higher than when 6,400 kg per ha of a 17:18:17 NPK fertilizer was applied. Napier grass was shown to tolerate fairly high rates of mixed effluents when surface irrigated. The only drawback is its adverse effect

/on the

Table 20 Amount of Major Nutrients Contributed by the Rubber Effluent (at 1.27 cm and 3.81 cm r.e.m.) Per Year in the Rubber Area and Their Projected Equivalent Fertilizer and Cost

Nutrient	Amount (kg/ha/year)		Equivalent fertilizer (ka/ha/year)		Equivalent fertilizer cost		
	1.27 cm	3.81 cm	1.27 cm	3.81 cm		M$	M$
N N	1,333	3,999	6,348	19,044	Ammonium sulphate	2,285	6,855
P_2O_5	192	575	533	1,599	Rock phosphate	138	415
K_2O	943	2,829	1,572		Muriate of potash	487	1,461
M_gO	91	273	337	1,011	Kieserite	128	384
				Total		3,039	9,117

Source: Mohd. Tayeb (1979)

Table 21 Effect of Rubber Effluent Application on Oil Palm Yield
(Tonne/ha/year)

Year	Effluent	Control			
	No fertilizer	Received fertilizer according to routine estate's practice			
	1970 planting	1970 (1) planting	1969 (2) planting	1969 (3) planting	Mean of control
1975	24.36	24.53	24.51	23.98	24.34
1976 (4)	25.31	24.71	22.59	19.49	22.26
1977	26.27	20.84	22.89	20.85	21.53
1978	26.91	23.57	20.83	22.21	22.20
Mean (1976-1978)	26.16	23.04	22.10	20.85	22.00
Mean %	119%	-	-	-	100%

(1) Away from the effluent application area.

(2) Missed one application of fertilizer from end of 1977 till early 1978

(3) Near to the effluent application area

(4) Effluent application started as from January 1976 onwards.

Source: Mohd. Tayeb (1979)

on the dry matter. The use of star grass with a higher dry matter content can easily overcome this drawback and therefore may be considered as a better choice than Napier grass.

Similarly, Zeid (1975) showed that the optimum rate of rubber factory effluent application was estimated to be about 5000 to 7000 litres per ha per application at 45 day intervals. Yield of dry fodder grass of up to 33 tonnes per ha per year was obtained by the use of effluent alone. Further work showed that by mixing ammoniated skim with acid serum higher rate of the effluent could be beneficially used. Recent investigations have also shown that bowl sludge applied at the rate of 2.5 tonnes per ha increased yields of pusa giant grass two-fold giving rise to 220 tonnes per ha per year. These clearly indicate the potentials for the use of the effluent, as a direct source of nitrogen for pasture.

Legume Production

Lowe (1968) and Pushparajah et al (1975) demonstrated that bowl sludge could be a suitable phosphate fertilizer. Mahmud (1976) showed that it was quite suitable for the growth of legumes. Compared to seven commercially available phosphates, bowl sludge application resulted in the highest dry matter yield of Pueraria.

Rubber and Oil Palm Crop Production

Mohd. Tayeb (1979) discusses the potential of both concentrated latex and crunch rubber factory effluents as an irrigated fertilizer for both rubber and oil palm crop production.

Two separate investigations were carried out to study the long term effects of land-disposal of a mixed rubber effluent from factories processing concentrate latex, cup-lump and skim rubber and oil

/palm.

palm.

At the time of study, the oil palm field had been irrigated with 1.91 cm (0.75 in) rain equivalent per month (r.e.m.) of effluent for about three years. The soil was a Seremban series (Plinthic Paleudult). The effluent used contained an average of 690 ppm N, 40 ppm P, 309 ppm K, 26 ppm Mg and 165 ppm Ca with a pH of 7.53. On a Rengam series (Typic Paleudult) soil, the rates of effluent used in the rubber area for the last five years were 1.27 cm (0.50 in) and 3.81 cm (1.50 in) r.e.m. The average composition of N, P, K, Mg and Ca was 875, 55, 514, 36 and 224 ppm respectively with a mean pH of 6.87. In both areas of study, the irrigation method used was the furrow system.

Both rubber and oil palm responded positively to the nutrients, particularly N and K, and moisture in the effluent. Good overall growth and yield performance was observed. At 3.81 cm r.e.m. and on a normal single-cut system, the rubber yielded 18% more than the control and 15% with Ethaphen stimulation. Marked improvement in yield was also observed on a double-cut system comparing stimulation with Ethaphen and Stimulex giving respective yield increases of 18 and 11 per cent over control. Yield increase of about 19 per cent fresh fruit bunch (FFB) over control was obtained in the oil palm field receiving effluent.

For soil around the furrow region, there were accumulation of P and to smaller extent K and Ca. There was a marked increase in the population of viable and nitrifying bacteria and fungi. Greater proliferation of tertiary and quaternary oil palm roots and feeder roots of rubber was observed. There was an

/obvious

obvious trend of increased soil available water capacity and moisture retention measured at 1/10 and 1/3 brs. Physically, the total aggregation, aggregate stability and total porosity decreased slightly and bulk density increased marginally in the oil palm field. This could be more due to the corrosive action of the effluent flowing at higher rate over steeper slope in this particular area.

The study shows a good potential for the use of rubber effluent on nature rubber and oil palm. Further work is currently being done.

Results of the abovementioned pilot study on rubber and oil palm irrigated with rubber factory effluent are shown in tables 21 and 22.

(iv) Future Developments

Over the past three years researchers in the field of treating palm oil mill effluent to meet the staged implementation of Malaysia's new environmental standards have investigated and installed commercial pilot scale and disposal schemes. Without pretreatment of palm oil sludge the use of this type of effluent has been found unsatisfactory and could possibly lead to continued partial pollution of waterways and streams. With the development of Censor III as shown in Figure 8, or with anaerobic digestion which produces methane as developed by Sime Darby, further aerobic treatment would result in a pollution free discharge which would still contain a considerable quantity of dissolved solids mainly in the form of inorganic salts (mainly potash). Serious consideration should be given to irrigating this liquid back on to the oil palm plantation or some other commercial crop area.

Liquid effluents from all agro-industrial plants should be considered as a potential source of plant nutrients, provided adequate pretreatment has been carried out to minimise the pollutant properties of such effluents.

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The composting and intermediate utilization of ligno-cellulosic wastes for mushroom cultivation or animal feed should be further developed to provide organic fertilizers such as has been demonstrated using oil palm pericarp fibre. Trials have successfully demonstrated the use of such composted residues as a suitable soil ameliorant for the reconditioning of tin mine sand for the production of vegetables (Graham 1976).

d. Construction materials, paper and handicrafts as end-uses

(i) Present uses

The use of straw for thatching roofs and walls has been a well established practice for many centuries. Likewise people living in coconut production areas have utilized leaves, shells, husk and trunks for many different purposes including roofing, bedding, building frames and kitchen utensils. More recent examples are illustrated in the Philippines Coconut Authority (PCA) presentation "Coconut The Tree of Life" and the uses of this magnificant plant are listed in fig. 10. In the Philippines, there has been considerable development of the cottage handicraft industry to supply the tourist trade with a wide range of handicrafts made from parts of the coconut plant.

In Malaysia, the palm kernel shell which is not used for fuel in the mill's boilers is used as a road surfacing material for the mill yard. It is particularly used in conjunction with laterite fill for improving roads in swampy areas.

In Thailand and the Philippines, rice husk ash has been commonly used as a fill material for house and factory compounds and is used in combination with sand and other aggregate materials to ensure a good quality foundation.

Rice straw sugarcane bagasse and coconut husk have recently been used as a source of raw materials for particle board and cement panel manufacture in Thailand, the Philippines, Malaysia and Pakistan. To ensure that the particle board product meet British, Australian or American standards, a considerable quantity of binding

/resins

resins had to be incorporated into it which may be why some factories have discontinued production, as the price of resins has risen considerably since 1976.

Paper manufacturing using sugarcane bagasse (which is surplus to the mill's fuel needs) has been established for a considerable period of time in both Pakistan and Thailand while rice straw is also used as a raw material in Thailand. Sugarcane bagasse is processed into pulp in the Philippines for export to China for paper manufacture.

In Pakistan, the sulphite waste water from the pulping process is a pollution problem that is being investigated by the Pakistan Council for Scientific and Industrial Research (PCSIR).

In Thailand the Siam Kraft Paper Co., Ltd. produces 60 tons of pulp from 200 tons of bagasse per day which uses a caustic digestion system. The pith and some bagasse is used as a fuel source and the chemicals are recovered and recycled. Because the bagasse fibre length is too short for container paper and paper board, imported pine pulp is the main input. The following figures indicate the percentage composition of various materials in this pulping process :

Pine pulp	60%
Bagasse pulp	30%
Waste paper pulp	10%

The factory has a capacity of 300 tons of Kraft paper per day and produces about 90,000 tons per year.

(ii) Immediate potential uses

The Rubber Research Institute in Kuala Lumpur has investigated and developed to a commercial pilot scale the utilization of rubber tree trunks for furniture and timber panelling for internal use. Rubber wood has also been used as a component in the manufacturing of paper by Japanese interests.

/In the

In the Philippines, considerable research has been carried out by the Forest Products Development Commission (FORPRIDECOM) into the use of coconut trunks as a potential construction material both as timber and as a raw material for particle boards. Some of the research has been advanced to pilot stage projects. Tamalong (1978) has reported the results of various studies by the above agency in which it has been found technically feasible to produce bag type paper and particle board from coconut stems. In the case of particle boards, the coconut stem particles mixed with wood particles in a 1:1 ratio was used with a bonding agent of 8 per cent urea formaldehyde and 10 per cent resin. One cubic meter of coconut trunk made 10-11 panels 12.70 mm x 1.22 m x 2.44 m which conform to Australian and British specifications. The report also gives the results of various tests carried out on coconut timber as shown in table 22.

/Table 22

Table 22 Physical and Mechanical Properties of Coconut Stem[a/]

Property	Unit	Position along cross-section	
		Hard Outer layer	Core
Moisture content, %	Present	121	287
Specific gravity[b/]	-	0.530	0.299
Static bending			
Stress at proportional limit	kg/cm^2	310	144
Modulus of rupture	kg/cm^2	527	242
Modulus of elasticity	$1000\ kg\ cm^2$	73.6	30.6
Compression parellel to grain			
Stress at proportional limit	kg/cm^2	169	73.7
Maximum crushing strength	kg/cm^2	294	123
Modulus of elasticity	$1000\ kg/\ cm^2$	109	47.8
Compression perpendicular to grain			
Stress at proportional limit	kg/cm^2	38.4	18.6
Shear parallel to grain			
Maximum shearing stress	kg/cm^2	58.1	22.5
Hardness[c/]			
Side	kg	524	137
End	kg	488	117
Toughness	kg/cm/ specimen	323	175

a/ All tests conducted followed the procedures of the ASTM Standard Methods of Testing Small Clear Specimens of Timber ASTM Designation:- D143-52. Part 16, 1970 Annual Book of ASTM Standards. American Society for Testing and Materials. Philadelphia. Pa.

b/ Based on oven-dry weight and volume at test.

c/ Load required to embed a 1.128 steel ball to 1/2 its diameter.

Source: Tamolan (1978).

From the 'Coconut Stem Seminar' held in Tonga in 197(under the sponsorship of the New Zealand Government aid programmes for the South Pacific region (New Zealand Government, 1978), there is a wealth of information regarding the utilization and potential development of use uses of the coconut stem. Several important recommendations resulted from this seminar which should be noted.

In most of the coconut producing regions, and particularly the Philippines, most of the coconut plantings are very old and are in need of replanting on a staged programme covering 40 years so that a continuous steady supply of coconut stems will be available.

The quality of the coconut stem as a potential construction material depends on the part of the stem used. The outer section is dense and suitable for saw timber while the inner core is soft and of poor strength but could be considered useful for chipboard dupping or pulping for paper manufacture. Bergseng (1976) has designed a technique for sawing coconut logs of different diameters so as to segregate the timber of different densities.

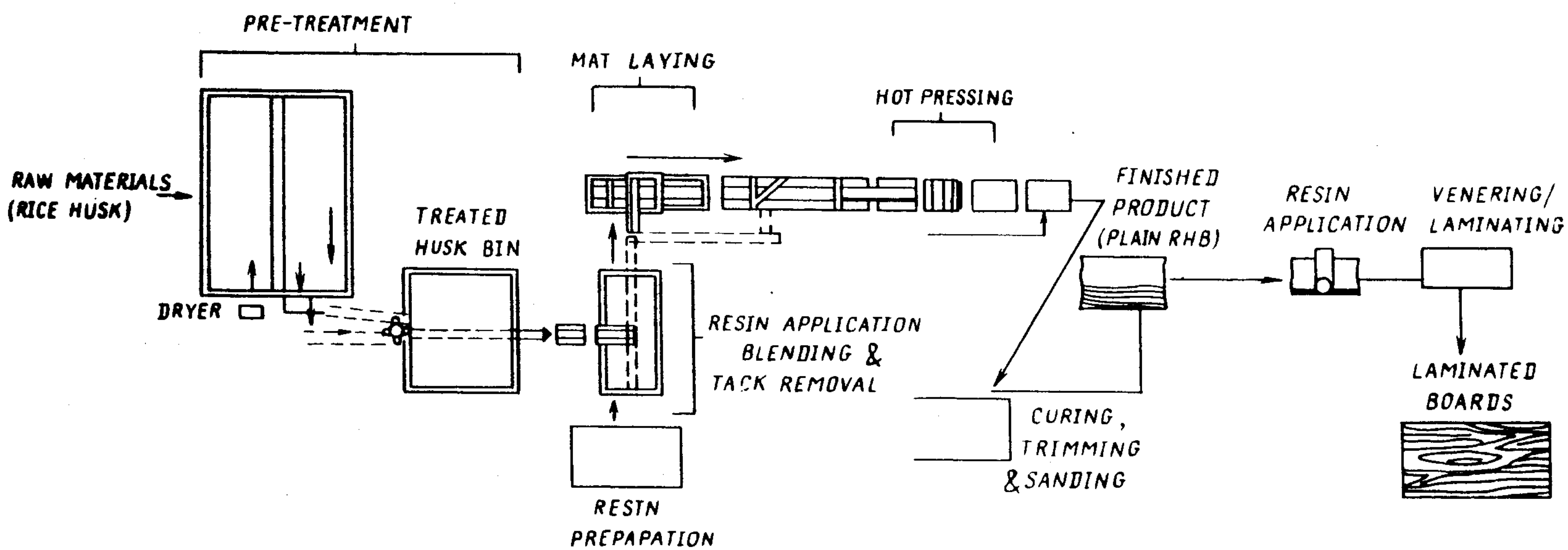
Due to the susceptibility of coconut stems, and any timber produced from them, to insects and decaying organisms, it is necessary to treat this timber with preservatives either by pressure methods or dipping in creasote. Mosteiro (1976) has reported on trials in the Philippines which have successfully preserved coconut stems for use as electric power and telecommunication poles.

FORPRIDECOM has also demonstrated the use of coconut stem timber in the construction of low cost housing and will promote this use in view of the 40,000 hectare per year replanting programme the Philippines is embarking upon. This will produce approximately 6 million cubic meters of timber per year (100 m^3 per ha).

A company, "Cortech Wellboard Asia Ltd.", which is a joint venture between Canadian and Philippine interests, has been set up in Manila and is embarking on the production of "Rice Husk Board" (RHB) which is aimed at utilizing the massive quantities of rice husk available, based on the following :

/Alternative

Figure 24 Rice Husk Board Process Flow Chart



Source: Cor Tech Technical Bulletin (1979)

Alternative sources of panel board production are available as by-products resulting from the agricultural industry. Baggase, wheat straw, various types of jute, stems, grasses and rice husk, to name a few, are available year after year and in increasing quantity as the agricultural output increases.

The rice husk board (RHB) is a panel board similar to the wood based particle board, except that it is made out of rice husk, a waste material derived from rice milling operations.

As a panel board, RHB enjoys a significant commercial advantage over particle board, plywood and other wood-based boards as it is cheaper to produce, is water and termite resistant and completely fire retardant.

Tests have also proven that RHB has excellent workability characteristics. All wood-work processes like sawing, drilling, nailing and screwing, are possible with RHB. In outward appearance, the board exhibits the aesthetic colour of the rice hull, preserved in its natural state.

The process flow chart is shown in fig. 24 for the production of RHB using a new synthetic resin reported in UNIDO report No. ID/WG89/23 1971. Table 23 presents a comparison between RHB and wood-based panel board, its nearest competitor. With recent increases in synthetic resin prices, the cost of the end-product will no doubt be somewhat higher than that predicted in past feasibility studies.

(iii) <u>Mid-term possibilities</u>

Rice husk ash (RHA) has been investigated as a potential pozzolanic material (a partial replacement for cement in paste and concrete mixes) by a number of research workers in Thailand and the Philippines. Results show that RHA can replace cement up to 20 per cent

/for

Table 23 Comparison of Properties between Rice Husk Board and Wood-Based Panelboard

	Rice Husk Board	Commercial Particle Boards
Board thickness (inches)	5/8	5/8
Board density (lbs./ft.)	50	45
Internal board (psi)	104	100
Modulus of rupture (psi)		
Control	2358	2350
24 hr. water soak	1740	1370
Accelerated Weathering	525	Delaminated
Modulus of elasticity (psi) x 103		
Control	391,000 psi	250,000 psi
24 hr. water soak	275	225
Accelerated weathering	150	Delaminated
Water soak		
% Thickness swell, 2 hr.	0.1	0.4
% Thickness swell, 24 hr.	7.2	10.7
Hardness (lbs.)	1130	-
Flame spread rating (ASTM-8-84)		
Termite resistance	No visible attack	Heavy wood decay
Fungus resistance (% loss)	7.4	215

a/ 10% mica

Source: Compiled test results from several North American Laboratories for mixes where strength is important and up to 30 per cent for low-load bearing structures. Cook (1976) describes the value of RHA as a pozzolanic material as follows :-

> It is shown that combustion of the husks at 450°C for four hours produces a material which conforms to a ASTM C618-72 Class N pozzolan. Tests were carried out to determine the bleeding, strength and volume change characteristics of cement - rice husk ash (RHA) pastes where the cement replacement ranged from 10 to 67 per cent. As would be expected, the bleeding rate of the pastes decreased as the cement replacement increased. The compressive strengths also decreased, though the 90 day strength for up to 20 per cent replacement indicated that, in general, addition of the RHA increased the volume changes of the pastes.
>
> The strength and volume change characteristics were also investigated for thirteen concrete mixes where the cement replacement varied from 10 to 40 per cent. The strength, both compressive and splitting tension, decreased as the cement replacement increased. However, the 90-day strength indicated that for up to 20 per cent replacement, the later age strength would be similar to that of the 100 per cent cement concrete. The creep, shrinkage and swelling characteristics of the concrete indicated that for up to 30 per cent cement replacement, the addition of the RHA was probably not significant if the influence of water cement ratio was taken into account.
>
> The results obtained from the limited research programme indicated that rice husk ash can be used as pozzolanic material, particularly in countries where mrre conventional artificial pozzolans, such as fly ash, are not available.

/Initial

Initial work carried out on RHA at the Asian Institute of Technology was concerned primarily with "village-burn" ash where the husks were converted to ash at temperatures of less than 300°C. Although it was simple to produce, the pozzolanic activity of the ash was very low, due primarily to the significant amount of carbon in it.

At higher conversion temperatures (greater than 500°C) approximately 25 per cent of the rice husk can be converted to ash and of that proportion some 90 per cent of silica. There is evidence to suggest that the ash consists essentially of tridymite and cristobalite. However, the presence of these minerals is highly dependent on the combustion temperature and at temperatures between 350 and 500°C, the ash consists of amorphous silica. The other mineral oxides present constitute between 7 to 10 per cent by weight of the ash the dominant minerals being potassium, magnesium, calcium and aluminum (in that order).

Sugarcane bagasse could be considered as a raw material (either flake or splinter particles) for the manufacture of particle board. Pablo (1979) found that a reasonable quality board could be produced provided the resin content was high enough. However, only the splinter type of board with at least 8 per cent resin passed the Australian standards specification for modulus of rapture and edge screw holding property while none passed the tensile strength test. Further development of production techniques are recommended if this use is to be pursued.

A recently developed process called Thermodyn could be used for a number of residues, including coir dust, to produce a wide range of composite board type products and is described as follows :

> Thermodyn is the name of an industrial process and of a new material, rigorously tested, and which production is based on world-wide licences.

/It

It uses (in Europe) a raw material composed of wood scraps of various origin, adequately processed. Thermodyn should not be confused with conglomerate processes based on synthetic bonding substances. As such, it is absolutely different from "bonded particle panels" and is it similar or even close to "reconstituted wood".

The originality of the invention lies in the discovery that ligneous and cellulosic components, when processed without bonding substances, in specially sealed molds, under high pressures (250-300 kg/cm^2) and high temperature (140-180°C), then cooled without releasing gases or pressure, could polymerise in contact with carbonyls and resin components existent in all vegetal materials.

Such components, due to the combined action of pressure and heat become gaseous and contribute to the molecular transformation in the course of a chemical chain reaction taking place inside the molds.

It uses any ligneous, wooden scraps such as, sawmill dust, wood fibres of all types, wood shavings, wood bark, roots, ligneous vegetal parts, seeds, straw, colza, corn,sugarcane residue, rice, cotton straw, etc....

Thermodyn, obtained through polymerization of the ligneous substance (average density: around 1.34-1.4 grems/cm^3), is fundamentally a new product obviously different from 'conglomerates', which are always lower in density.

When a certain volume of materials of vegetal origin, containing ligneous and cellulosic components, is subjected to combined heat and pressure, under precisely determined conditions and within

/rigorously 9481

rigorously controlled humidity, some of its components go through a chemical transformation during which the materials become thermally plastic.

Following complex hydrolysis and condensation reactions, mainly at the level of polyosis and ligneous components, new water-insoluble substances, similar to plastic materials of the 'duroplast' type, are created. It is essentially these new substances which give their characteristics to the Thermodyn processed material. Moreover, when high mechanical pressures are simultaneously exerted on the ligneous material, it is subjected to aviscoelastic deformation and a permanent densification. The direct consequences are: a reduction of internal stress, an increase in strength, an irreversible stability, as well as an increased resistance to humidity absorption. The described chemical reactions enable all vegetal materials with ligneous and cellulosic components to be used in the Thermodyn process.

Road Construction

Light weight rice husk ash fill can be used at approaches to structures such as bridges or culverts to reduce the differential settlement between the approach embankment and the structure itself. Although the cost is about double the cost of a normal highway embankment, it is still only one-half to two-thirds the cost of extending the bridge superstructure. Field compaction trials of rice husk ash were carried out during the construction of the Thonburi-Paktho Highway and indicated that 8 to 12 passes of a 2-ton vibrating roller were needed to obtain the optimum compaction level. Large thickness and density reduction factors of 2.0 to 2.5 were observed during compaction. Field CBR tests indicated initial CBR values of 5 to 10 which increased to values of 15 to 20 in several months due to the time reaction. This stabilization reaction also caused a marked drop in Benkelman Bean deflection readings on the finished pavement surface. Settlement measurements at these approach embankments indicated that rice husk ash was very effective in reducing settlements.

/(iv)

(iv) Future development

In the use of tree crops such as coconut as a source of timber, there will be a need to continue research into techniques of preservation.

For particle board manufacture, there is a need to investigate new types of resins which are both suitable for the types of raw materials being used and much cheaper than present supplies.

Based on Sutanto's (1979) recommendations, a paper industry from oil palm fibrous wastes may be developed, if the efficiency of the extraction process is improved and sufficient raw materials are economically available.

e. Chemical extracts as an end-use

A multitude of chemical products from agricultural residues have been identified and developed in western and developed countries including Australia and Japan in the ESCAP region. Bates (1964) has listed a range of products that can be obtained from ethanol or acetone butanol processes using molasses as a raw material (see figs. 5 and 6). Baret (1977) has shown how cellulosic wastes end carbohydrates from agro-industries can be upgraded to produce various end-products including chemical stock for further downstream processes, such as for the plastics industry (see fig. 25).

(i) Current uses

In the developing countries studied here, there are not many instances of chemical by-products being produced from agricultural residues. This is probably due to the existence of cheaper alternative sources such as petroleum, until recently.

Activated carbon is one example of a residue based chemical industry which is established on a viable commercial scale in the Philippines using coconut shell as a raw material.

/Figure 25

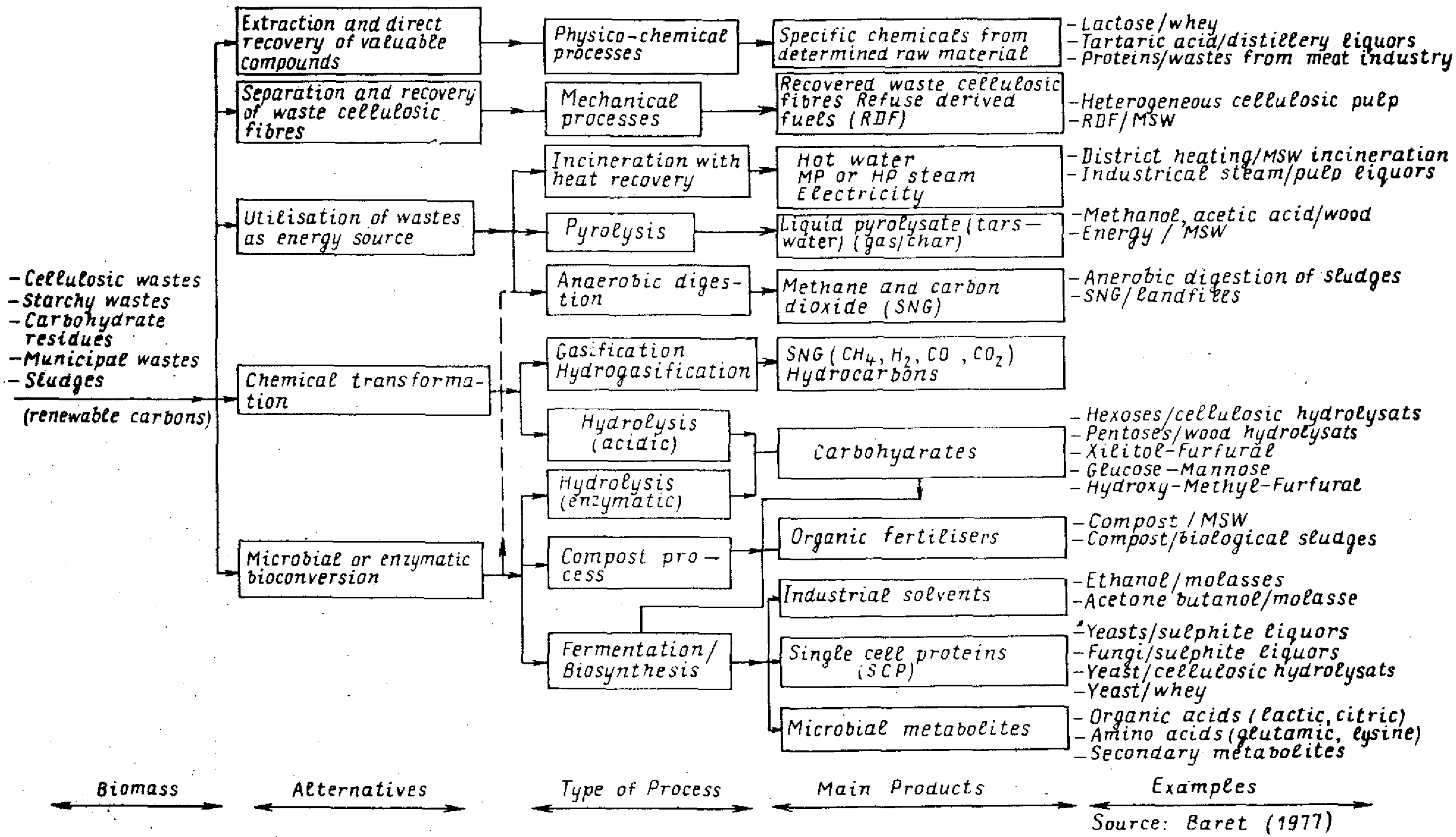


Figure 25 TECHNOLOGICAL ALTERNATIVES FOR URGRADING CELLULOSIC WASTES AND CARBOHYDRATES, RESIDUES FROM AGRICULTURAL AND FOOD INDUSTRIES

In Malaysia, with the development of downstream processing of palm oil involving refining fractionation and consumer product processing (margarine shorterning, cooking oil, soap, hydrogenated oil and stearin), there is a small quantity of glycerine produced which is a chemical feedstock for other chemical processes.

(ii) Immediate potential uses

As pointed out at the beginning of this section, the technologies for the extraction of a wide range of chemicals from agricultural and agro-industrial residues already exist. Given the necessary financial support, guarantee of adequate and consistent supplies of raw materials, good market potential and the provision of good technical and management skills, there are good opportunities for the development of some of these products.

FORPRIDECOM in the Philippines has identified the potential of using sugarcane bagasse, rice straw and coconut trunk as cellulosic materials for production of dissolved pulp which could be converted into rayon, celluloces acetate, cellophane, plastics lacquers and explosives. In conjunction with the Philippine Coconut Authority, it has also identified potential chemical and products from various components of the coconut palm.

Furfural

There has been considerable discussion of the potential of crop residues with a high pentosan content for the production of furfural. Figure 26 gives the process flow sheet for furfural production.

Conversion of crop residues into furfural

Some crop residues, particularly those accumulated in larger quantitites (bagasse, cotton seed hulls) could be converted into furfural. In addition, this process generates furfural residues which can be used as a forage for ruminants.

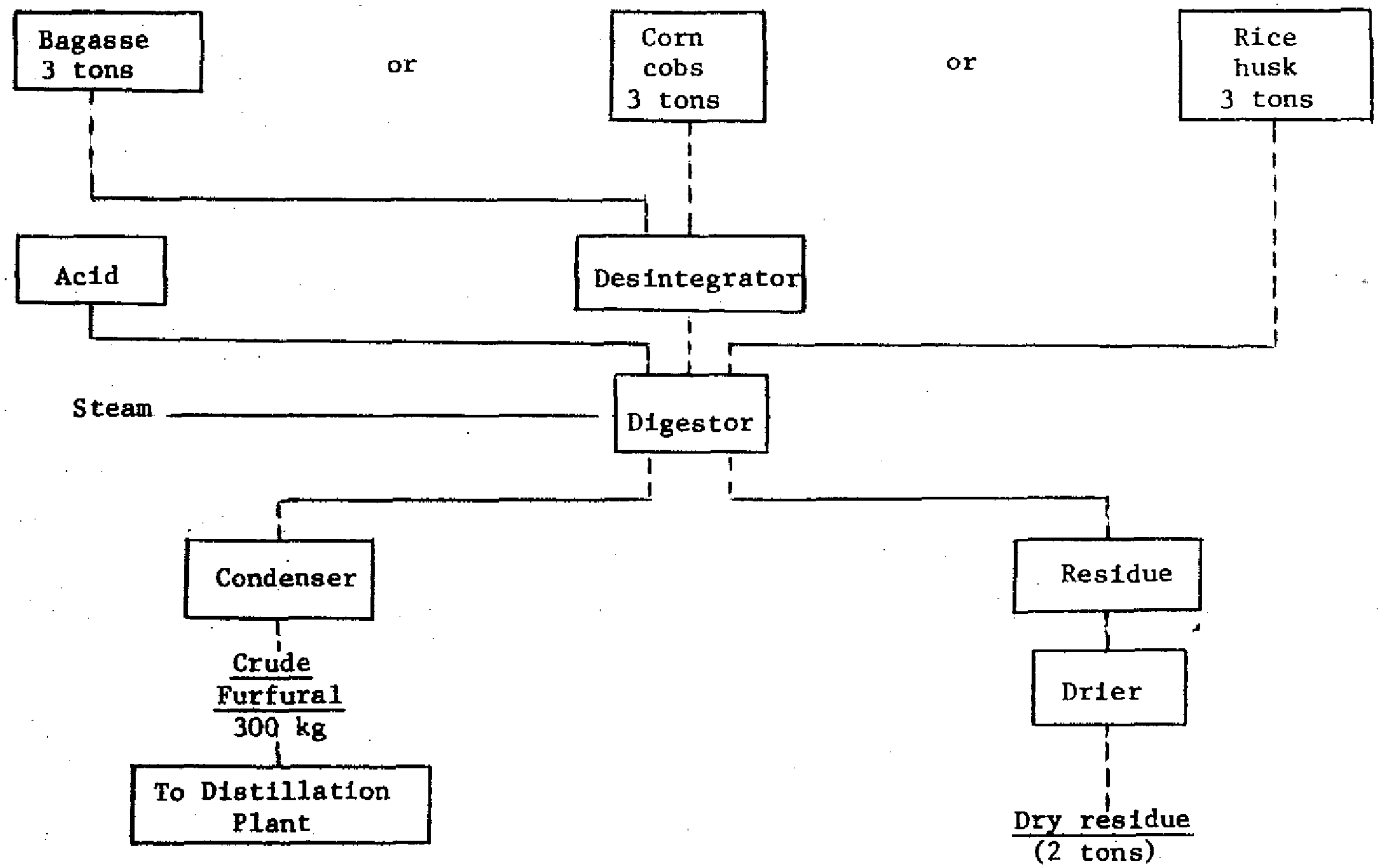
/Figure 26

Fig. 26 Furfural Process Flow Chart

Basis: 300 kg crude furfural per day

No. of units: 5

Location: Mini Fat Splitting Plants



It is estimated that each mini plant for producing crude furfural will require a capital investment of US$ 27,000. Thus, 5 mini plants will have a total capital investment of US$ 135,000. The distillation plant will have additional capital investment of US$ 100,000. The total capital investment of the complex thus works out to be US$ 235,000. The gross return per annum is expected to be around US$ 260,000. Source: Bhushan (1977).

Furfural as a chemical

Furfural is used for numerous industrial processes, such as solvent refining of luoricating oils, butadiene, resin and other organic materials, a solvent for nitro-cellulose, cellulose acetate, shoe dyes, an intermediate stage for production of tetrahydrofuran and furfural alcohol, phenoloc and furan polymers, a wetting agent in the manufacture of abrasive wheels and brake linings, weed killer, fungicide, adipic acid and adiponitrils, production of lysine the refining of rare earths and metals, flavourings and road construction.

Furfural yields

Sunflower hulls and maize cobs are the richest source of pentosans from which furfural is derived. Furfural yields of some relevant crop residues are shown in table 24.

Table 24 Furfural yields of some crop residues (average values)

Crop residues	Pentosane content percentage	Furfural yields	
		Maximum percentage	Minimum percentage
Sunflower hulls	32	11	7.0
Cottonseed hulls	25	3	5.5
Maize cobs	32	11	7.0
Bagasse	26	9	6.5

Source: Muller (1978)

/By-products

By-products and wastes derived from furfural production

About 20,000 tons of crop residue is an economically viable unit which would give approximately 1,400 tons per year of furfural. Other products produced from the above-mentioned volume of crop residues would be methanol (100 t/yr), acetic acid (3.5 t/yr). It should be noted that furfural production is considered economical when the level of pentosans in the raw material is over 20 per cent.

Furfural production could also be utilized as a forage substitute. About 20,000 tonnes of raw material would generate 15,000 tonnes of furfural wastes (75 per cent of the raw material input), an amount which could feed 2000-3000 head of beef or 1500-1800 dairy cattle. The nutritive value of furfural waste derived either from maize cobs, sunflower hulls or wood waste is given in table 25.

Table 25 Chemical Composition of Furfural Waste (on DM basis)

Constituents	Crop Residues Used for Furfural Production		
	Maize cobs	Sunflower hulls	Wood waste
	%	%	%
Crude protein	3.00	5.63	1.47
True protein	2.71	4.12	1.09
Digestible protein	2.14	3.75	0.86
Ether extract	0.39	1.35	0.83
Crude fibre	37.10	38.91	41.70
Nitrogen free extract	56.53	47.30	54.78
Ash	2.98	6.81	1.42

Source: Muller (1978)

/Despite

Despite the rather high fibre content of furfural wastes, the chemical process contributes to the liberation of cellulose from the cellulose-lignin bond and thus the digestibility of furfural waste for cattle is higher than that of traditional forage of similar nutritional composition.

(iii) Midterm Possibilities

Both the Korean Institute of Science and Technology (KIST) and the College of Arts and Science University of Philippines have recognized the need to produce cheaper enzymes of high activity from local raw materials such as rice bran, rice husks and rice straw. Del Rosario (1978) reports on studies of producing cellulose by Trichoderma Viride on the above substrates.

The Korean Institute of Science and Technology (KIST) has reported the production of a amylase and glucoamylase from local raw materials which in commercial production are available as glucose isomorase. It is reported that the product is half as costly as the same type of enzyme available from European sources.

KIST has developed a pilot plant capable of producing enzymes from rice husk and rice straw which will need further adaptation trials and development before establishment of a commercial production plant.

(iv) Future Developments

Further research will be necessary to develop the production of chemical feedstock from local raw materials especially with the recent changes in the petrochemical industries. There are distinct possibilities of producing chemicals such as precusors for detergents, plastics and synthetic textile fibres.

New technologies are also being developed to improve the economic viability of producing furfural and activated carbon from indigenous raw materials such as rice husk. Bandey (1979) has proposed a pilot plant development for the production of furfural or more simply activated carbon from rice husk using a concentrated salt solution for Pakistan instead of the normal acid activation process which is expensive

/because

because of the need to import acid. A simplified process flow chart for this newly developed technology which might be suitable for Asian countries is shown in fig. 27.

f. Water as an End-Use

From the problems observed in several of the countries visited by the ESCAP/UNEP mission, it is evident that water must be considered as an end-use. Until the present, most agro-industires have regarded water based residues as a waste to be discharged and have thought that there was more than sufficient available water as an input material. However, with the recent rapid and planned expansion of the palm oil, industrial alcohol, sugar, paper and rubber industries, water is becoming a scarce input.

Besides meeting the recently imposed and planned environmental standards, pollution control methods should be developed with the objective in mind that treated water could be recycled or discharged into a stream or water-way of a suitable quality for the next downstream consumer.

An expansion of an industrial alcohol plant in Thailand illustrates the importance of this concept. At present the 60,000 litre/day plant consumes 200-300 m^3 per day of water which is discharged as stillage into 11 hectares of anaerobic, facultative and acrobic ponds from which it is irregated on to nearby sugarcane fields. There is no possibility of a bore well supply, and the rainfed dams do not supply much more than the present off-take requirements. For the planned expansion to 150,000 litres per day the water has to be recovered and recycled into the plant. Thanh (1979) discusses techniques of achieving these objectives.

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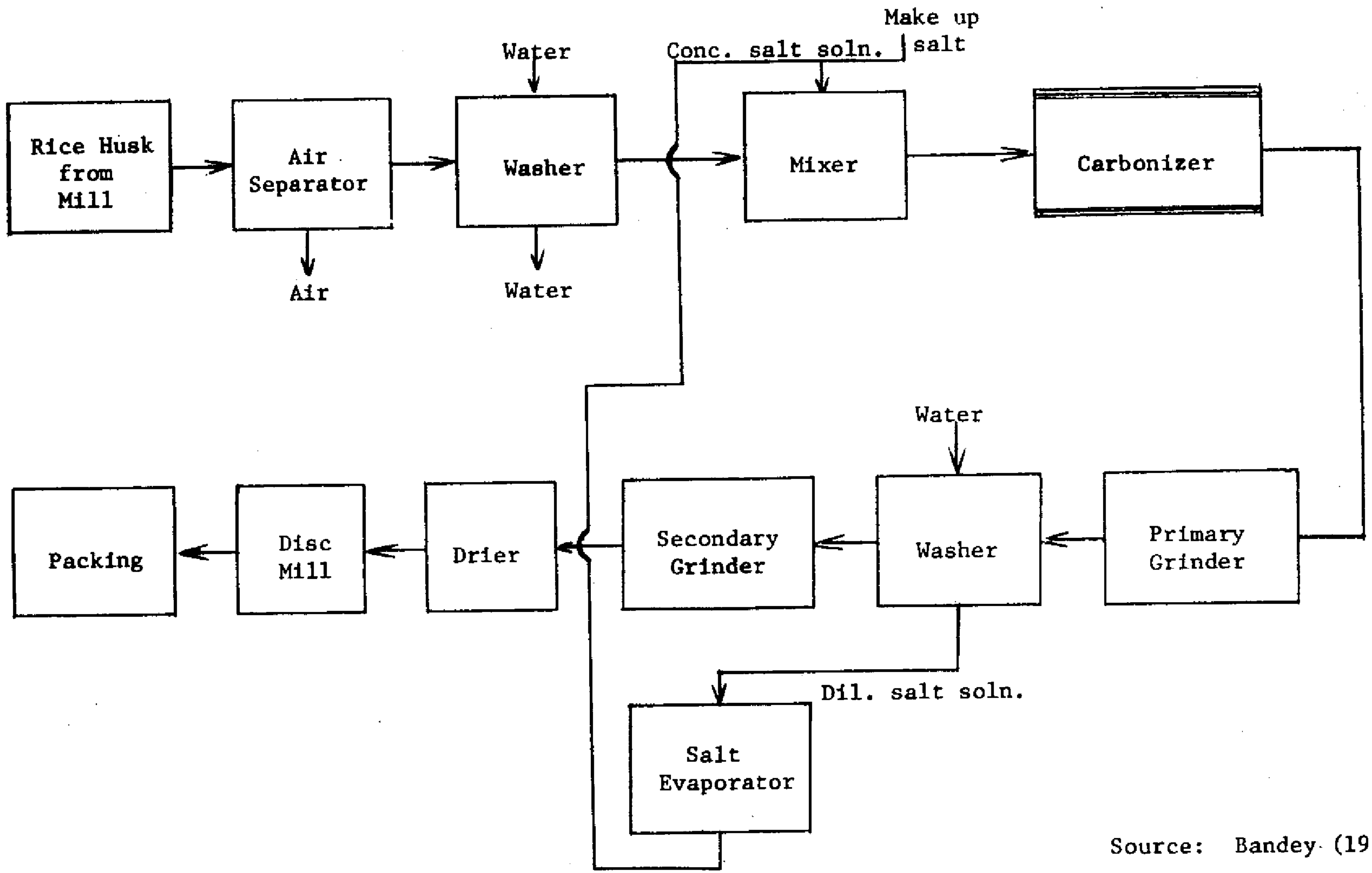
Fig. 27 Pilot Plant for Activated Carbon from Rice Husk



Source: Bandey (1979)

V POTENTIAL RESEARCH AREAS

Even though certain suggestions have been made as to possible future developments there are certain areas of research which should be identified as being worthy of serious consideration for support in the development of residue utilization.

a. The ASEAN Subcommittee on Protein has proposed and is setting up a project "The Management and Utilization of Food Waste Materials" which is based on a report by Bychanan and Oei (1978) the summary of which is given below :

> Three promising processes have been identified as offering potential for the effective management an utilization of food waste materials.
>
> (i) Biogas fermentation
>
> Biogas fermentation (methane), now widely applied for animal wastes, may be adapted to the treatment of wastes which accumulate in large quantities from food factories. Other fermentation processes will also be investigated to convert food wastes into other useful products such as citric acid and vinegar.
>
> (ii) Reverse osmosis
>
> Reverse osmosis and ultrafiltration are processes which have been recently developed to separate substances by passing them through special membranes. Recent technological advances have lead to the development of new membranes which are more efficient, durable and economical than before. Membrane processes now appear to offer an appropriate technology for the ASEAN region. Skilled manpower and experimental pilot plants are required in the region to capitalize on these new technological developments. Establishment of a team of ASEAN scientists, working on

/this

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this new technology, sharing their resources and experience, is expected to strengthen efforts to adapt the technology to the requirements of the ASEAN region.

viz. - Protein recovery from rice starch and mung starch factories

- Recovering clean water from dilute factory effluents

- Concentrating coconut water wastes for canning or bottling

- Recovering drinkable water from polluted sources

(iii) Feedstuffs

Food wastes which cannot be used for human consumption may be fed to fish, ducks, chickens, pigs or cattle. If animals are not available to eat these wastes on the spot then they may spoil.

A pilot plant can check the economics of preserving such wastes by drying and making them suitable for transportation by pelletising.

b. KIST in the Republic of Korea has developed its research programme on the production of cheap enzymes such as cellulase, zylase and other saccarification enzymes to a pilot plant stage and are continuing their work on the conversion of ligno cellulosic residues into such useful chemicals.

c. Professor A.H. Bandey of the Department of Chemical Engineering in the University of Engineering and Technology Lahore, Pakistan has developed on a laboratory scale a successful system of carbonizing rice husk into activated carbon using a cheap, locally available salt as the activating agent. He proposes to develop a semi-continuous pilot plant to improve the process efficiency and enable an economic evaluation to be made as follows :

/Bench-scale

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Bench-scale experiments in this department have brought out the definite possibility of converting rice husk into good quality activated carbon, comparable with commercial grade product being marketed by Japan, U.K. and West European countries.

The standard method of activation being followed for a variety of cabronaceous substances utilizes mineral acids (normally sulphuric acid) as the activating agent. This approach leads to problems of corrosion, expensive materials of construction, extensive washing to free the product from traces of acid and consequent high cost of recovery from dilute acid solution. In order to avoid these difficulties, salt activation methods has been tried with considerable degree of success. It appears that the constituents present in the husk lend themselves to equally efficient activation with salt, thereby reducing the otherwise high costs of inputs and operation.

The department now proposes to study the process on a semi-continuous pilot plant scale so as to examine the commercial possibilities of manufacturing activated carbon locally, and to work out its economics more precisely. It is estimated that the cost of producing activated carbon in this manner would be less than the import.

The process flow chart for this proposed project was shown earlier in fig. 27.

d. <u>The PCSIR laboratories in Karachi, Pakistan</u> proposed a project to investigate the conversion of agricultural wastes into "Bio-fertilizers" using accelerated microbial decomposition techniques so as to minimize the import of fertilizer and to alleviate the aggravation of salinity which is currently a problem with the use of inorganic fertilizers. The studies include the use of phytohormones and nitrogen fixing micro-organisms to enhance the economics of such a production system (Iftikan 1979).

/e.

e. Dr. F.N. Tamolang of FORPRIDECOM has developed a laboratory scale cabonizer for the simultaneous conversion of rice husk and coconut shell into high quality charcoal in the same retort. The equipment for doing this is illustrated in fig. 28.

There is a need to design and develop a pilot plant scale model to enable the proper design for commercial plants.

The rice husk charcoal from this process would provide a better quality fuel that could be used at the site of production for process energy supply or briquetted or pelletised for transport to other consumers.

f. Researchers at the University of Malaya propose a multi disciplinary approach to investigating a number of areas related to agricultural and agro-industrial residue utilization.

(i) Continued development of solvent oil extraction, conversion of solids into animal feed and final water treatment as a means of reusing water either through a recycling system or providing useable water to the next consumer in the water supplying network.

(ii) The development of suitable processing techniques to produce high quality feed from cassava leaves while economically eliminating the cyanogenic glucocide toxicity problem, based on Webb's (1978) report.

(iii) Studies into ways and means of conserving and more efficiently utilizing low cost energy that is available in sugarcane and oil palm industries.

(iv) Investigations into the production of various types of chemicals from the plentiful supply of residues available from the seven crops studied here.

(v) The development of a practical and economically viable system of harvesting, processing preserving and packaging of algae which has been grown on liquid effluents such as rubber and palm oil mill liquid wastes.

/g.

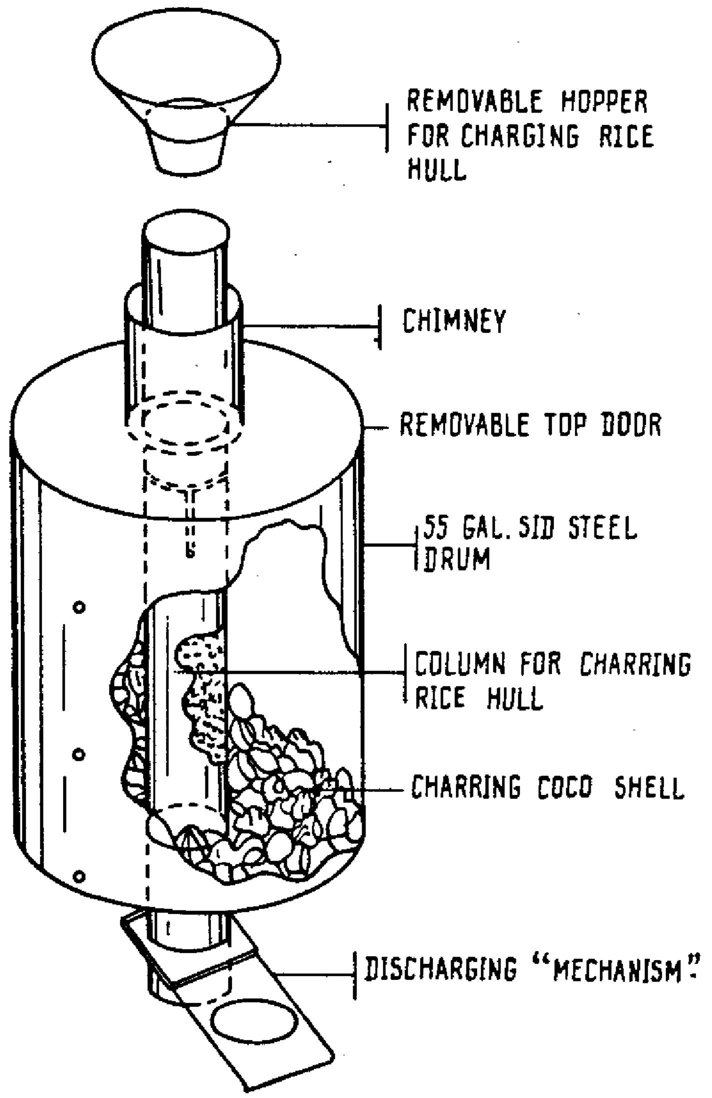

Figure 28 Rice Husk Charcoal Carboniser.
Source: Tamolang (1978)

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g. Constraints to the Adoption of Technology

(i) Logistical factors

There have been many suggestions made by very competent people as to the prospects of setting up secondary industries based on the integration of agricultural wastes which are an extension of laboratory experimentation or transfer of well proven economic technologies in developed industrial nations. However, these technologies have and will continue to fail in their implementation in undeveloped nations because of a number of factors of which logistics is a most important one. In this respect a few points that should be considered are :

(a) Where the production of a crop is on a small holder scale and the residue occurs as a result of an on farm operation, quantities are usually small and because of the isolated and scattered location of each supply situation it is difficult and uneconomic to collect and sustain a reliable supply to a centralised processing plant. This is the case where the production of furfural from rice and maize residues is concerned and to a lesser extent when considering the use of oil palm pericarp fibre for paper production.

(b) Tha lack of cheap transport for the collection a and transfer of bulky raw materials such as coconut husk and shell to central large scale charcoal and activated carbon factories or in the future chemical extraction plants may have a serious effect on the economic vialility of a new industrial project based upon such raw materials. This also applies to the development of a flour substitution project using 100,000 nuts per day in the central Philippines as the transport vehicles operate on gasoline and because of road conditions and poor reception facilities at factories can only make one trip per day which, before the recent increases in petroleum prices, resulted in a transport cost of US$ 0.54 per ton mile.

/(c)

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(c) At present there is generally a lack of handling facilities for the economic storage and collection of residues which have a potential for downstream utilization.

(ii) Traditionalism

With most agricultural industries especially those which have been developed during the colonial era there has been a deeply ingrained tradition of agronomic practices, successfully developed during past generations which have been passed down in almost legendary fashion. This has resulted in a strong resistance to change of the status quo.

(iii) Conservatism

Once a system has been devised and proven successful, there exists in well established companies a degree of conservatism whereby it is deemed correct to beware of change if there is risk involved. This is true even though there is conclusive proof that given good management and the availability of the correct equipment and expertise the new venture is a very sound investment.

(iv) Technical Problems

There is a tendency for new ventures to try and short-cut on the full adoption of recommended equipment materials, technical expertise and properly trained personnel. There have been many instances, some quite recent, where projects have failed due to poor management and the lack of good technical staff to operate the scheme both in field and in factory. When an industry is new to a particular region (it may be well established in other countries) which has a proven track record, it is important to import the necessary technical expertise from top management to the factory floor or field until such time as local personnel have been trained to the extent they have developed a "sixth sense" about the industry.

/(v)

(v) Markets

Prior to embanking on what appears to be a technically feasible scheme, much care should be given to ensuring that there is a ready and profitable market for the produce concerned. This problem has arisen on many occasions where low quality fibrous wastes have been considered as good cattle feed only to find out that there were not sufficient cattle or that they were so scattered and were only owned by subsistence level farmers that the product could not be sold.

(vi) Fiscal Problems

Finally a problem which appears to beset many adventurous developers who are convinced that their new enterprises are economically feasible is that of being able to find sufficient financial support for a risk venture. Most banking and financing institutions in the region are only prepared to provide financial facilities for industries with a proven track record, i.e., investment ventures. When it comes to providing loans for new ventures banks classify them as risk ventures and either reject the request or make the terms so unattractive the project will not be able to get off the ground.

(vii) Other Constraints

There are probably many other problems to be overcome such as licences, government duties, land acquisition and other administrative matters all of which must be considered when setting up an annex or a new industry to utilize these residues.

VII AGRO-INDUSTRIAL INTEGRATED DIVERSIFICATION

This concept was referred to briefly in section IV (a) under energy as an end-use. Basically it involves the integration of two or more agricultural industries to utilize the available resources more efficiently and at the same time diversify the operation.

/A good

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A good example of this concept is the proposed development of an ethanol distillary using cassava as its raw material alongside a plant using sugarcane so as to ensure that both operations are energy self-sufficient thus overcoming the main drawback to using cassava to produce ethanol. Yet another case is the proposal in Malaysia to operate a rubber factory alongside an oil palm mill so as to utilize surplus energy from the generation of methane from the palm oil sludge for drying the rubber. Also in Indonesia there is a plan to set up a sugarcane production project on an existing tobacco scheme to utilize the fallow land which lies idle for 4 years due to the rotation cycle necessary to control phytophthora infection.

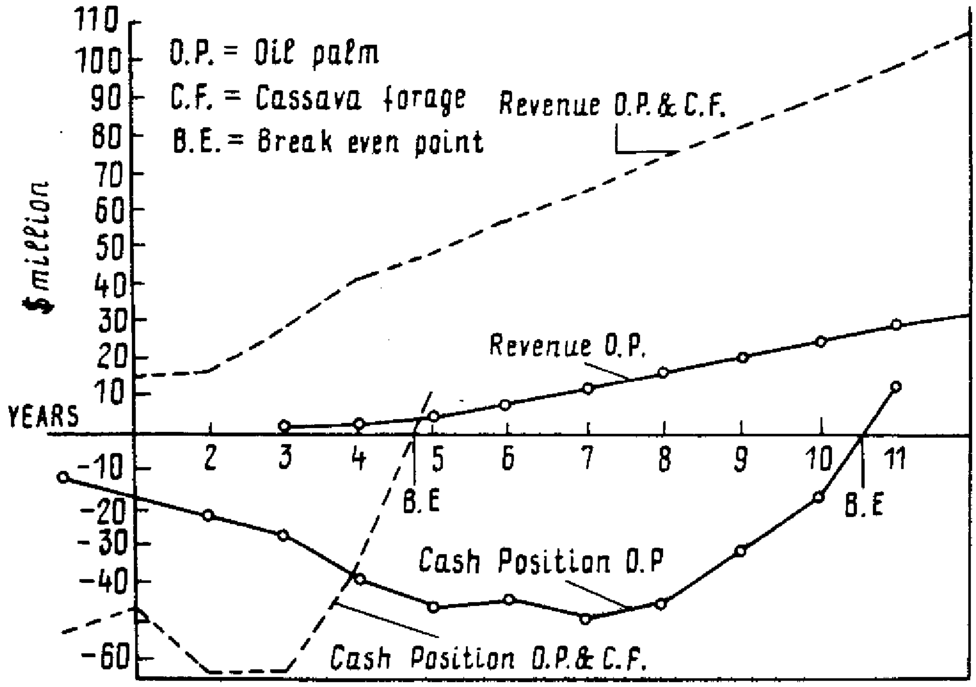
A proposal made by Webb (1978) envisages the development of an animal food (for export) project side by side, or in conjunction with an oil palm plantation on an area ratio of 1:1. The factories would be adjacent to one another so that the animal food factory (processing high protein cassava leaf or grass) could obtain the surplus energy from the palm oil mill and at the same time prossess the sludge solids into animal feed. An added advantage of this concept would be the potential to rotate the two crops. Also there would be a much quicker payback on invested capital as is demonstrated by the graph in fig.29. With the current problems of inflation and rapidly rising energy costs this concept warrents serious consideration for developing countries in this region.

VIII CONCLUSION

While there are probably many aspects of residue utilization not covered in this paper it should provide an adequate guide as to the technological problems in assessing and developing plans for solving important problem issues related to the protection of the environment. It is important that the problem be identified accurately before embarking on a particular programme to develop an end-use for a residue that will be economically viable.

/There are

Figure 29 Cassava forage and Oil palm vs Oil palm. Revenue and Cash Position



Note: - (a) The above comparison is for an estate of 11,000ha.
(b) Cassava forage and oil palm option represents 5250ha of oil palm and 5750ha of cassava forage.
(c) For O.P. and C.F. the total capital investment is estimated at M$ 135 million, but only M$ 65 million maximum capital outgoings.

Source: Webb (1978)

There are many instances of uses of residues that have been in existence for many years that could be easily adopted by other countries at very little expense. This is a logical and practical approach to adopt in the light of present economic trends, viz. rising fuel costs.

From local pilot scale and well established developed countries' technologies there are a number of instances where it is possible to adopt this technology immediately. The only limitation to the production of end-products from various residues coming on stream would then be time, physical and financial constraints. However, a word of warning: It is necessary that a comprehensive and accurate economic assessment of each venture be conducted before embarking on any project of this nature.

There is a wealth of research information available within the region as well as that from outside which is related to the problems of residue utilization, which if developed from the laboratory stage through the pilot plant to the commercial scale could help provide a more diversified economy and help buffer the impact of inflation.

As has been identified by Dhira (1979), there is a need for an international forum to enable efficient dissemination of technical information to all countries in the region. Moreover, the efforts of those involved in technology development should be effectively coordinated to avoid unnecessary duplication of effort and consequently a waste of finances and facilities.

Because of recent developments in the petroleum industry there has been much emphasis placed upon energy as an end-use. There is no doubt that in addition to the wide publicity given to the potential of sugarcane and cassava as photosynthetic sources for ethanol production, there is a vast potential for the use of other residues as energy sources. In this regard, there is an urgent need to rethink, redesign and improve operating efficiency of existing processing plants so as to utilize the available energy sources move effectively.

/Serious

Serious thought must be given to integrated diversification so as to economise on the utilization of natural resources and to stabilise the agricultural industries of the ESCAP countries. These industries have been subjected to the ravages of volatile markets for so many years, because most of them have relied on the sale of only a single product.

It is important that the correct technology be selected and that it has been fully evaluated from the economic, environmental, and socio-economic stand point. There is no doubt that with the technologies available a profit can be made from the correct utilization of agricultural and agro-industrial residues and at the same time protect the environment.

The overall concept of the assessment of utilizing agricultural and agro-industrial residues can be summarised as follows with a list of potential end-uses given in table 26.

In trying to assess the problem issues and the potential solutions in respect of utilization of agricultural and agro-industrial residues in the five countries studied the following approach was adopted.

(i) <u>Crops Considered</u>

- a) Rice
- b) Sugarcane
- c) Maize
- d) Cassava
- e) Coconut
- f) Rubber
- g) Oil Palm

(ii) <u>Residue End-Use Categories</u>

- a) Energy
    - i) ethanol
    - ii) solid fuels
    - iii) gases

/b)

b) Food (human) and animal foodstuffs

c) Fertilizer

d) Construction materials, paper and curios

e) Chemicals

f) Water

(iii) <u>Potential Adoption on A Time Base Classification</u>

a) Present Use

b) Immediate Potential-transfer of technology

c) Midterm Possibilities - technology in need of adaptive research and as a pilot stage of development.

d) Future Development - areas of needed research or research at the laboratory stage in need of development to the adoption level.

(iv) <u>Identification of Constraints</u>

a) Technological

b) Logistical

c) Psycological

d) Sociological

e) Financial (investment)

f) Economical

g) Geographical

i) climate
ii) topographical

(v) <u>Conceptual Development Strategies</u>

a) State of development

b) Socio-economic objectives

c) Present and future requirements

d) Impact of consequences of world wide inflationary trends.

e) Special consideration of the energy crisis

/Table 26

Table 26 End-Use Potential

End-use	Residue	Product	Time-base potential
1. Renewable energy source	Molasses	Ethanol	P
	Cassava	Ethanol	P
	Sugarcane	Ethanol	P
	Bagasse	Solid fuel	P
	Oil palm fibre	Solid fuel	P
	Coconut shell	Charcoal	P
	Coconut leaf	Solid fuel	P
	Cassava stems	Solid fuel	P
	Rice husk	Solid fuel	P
	Rubber wood	Solid fuel	P
	Coconut stem	Charcoal	I
	Coconut husk	Charcoal	I
	Ligno-cellulosic wastes	Char-oil gas	M
	Rice straw	Ethanol	M
	Palm oil sludge	Biogas	M
	Distillery stillage	Biogas	M
	Rice husk	Charcoal	M
2. Food and animal feeds	Rice bran and straw		P
	Maize stalk, cobs and husk	Animal feeds	P
	Maize gluten	Animal feeds	P
	Coconut meal	Animal feeds	P
	Oil palm kernel	Animal feeds	P

/Cake

End-use	Residue	Product	Time-base potential
2. Food and animal feeds (contd.)	Cake, stearin	Animal feeds	P
	Palm oil	Animal feeds	P
	Sugarcane bagasse	Animal feeds	P
	Rice straw	Compost (mushrooms)	P
	Sugarcane leaves	Animal feeds	P
	Cassava residues	Animal feeds	P
	Bagasse	Animal feeds	P
	Cassava foliage	Animal feeds	P
	Molasses	Animal feeds	P
	Molasses & nitrogen	Animal feeds	P
	Edible oil refining residue		P
	Rice straw (treated)	Animal feeds	I
	Bagasse (treated)	Animal feeds	I
	Rubber seed meal	Animal feeds	F
	Rubber seed oil cake	Animal feeds	F

/3. Fertilizer

End-use	Residue	Product	Time-base potential
3. Fertilizer	Rice straw (burnt)	Ash	P
	Rice straw (bulk material)	Composting night soil	P
	Oil palm bunch	Ash	P
	Sugarcane filter mud	Organic manure	P
	Coconut coir	Dry manure	P
	Rice straw	Organic manure compost	P
	Paper mill effluent (treated)	Organic manure	I
	Distillery stillage (treated)	Organic manure	I
	Sugar mill effluent (treated)	Organic manure	I
	Rubber effluent	Compost, organic manure	I
4. Construction materials paper and Handicraft	Bagasse	Paper	P
	Rice straw	Paper	P
	Rice husk	Particle board	P

/Bagasse

End-use	Residue	Product	Time-base potential
4. <u>Construction materials paper and handicrafts</u> (continued)	Bagasse	Particle board	P
	Rice/Straw straw	Thatch	P
		Particle board	P
	Coconut tree parts	Handicrafts	P
	Coconut stem	Timber	I
		Telephone poles	I
		Posts	I
	Rubber wood	Furniture	I
		Rough timber	I
	Coconut trunk	Particle board	M
	Ligno-cellulosic waste (thermodynes)	Particle board	M
	Rice husk ash	Pozzolanic material	M
5. <u>Chemicals</u>	Coconut shell	Activated carbon	P
	Coconut mill effluent	Vinegar	P
	Palm oil refining residue	Glycerine	P
	Rubber seed	Oil	P

/Molasses

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End-use	Residue	Product	Time-base potential
5. <u>Chemicals</u> (continued)	Molasses	Alcohol, citric acid, MSG, other organic acids	P
	Cassava pulp	Citric acid	P
	Palm kernel shell	Activated carbon	I
	Ligno-cellulosic wastes	Furfural	I
	Rice husk	Abrasives/ silica	M
	Rice straw and husk	Enzymes	M
	Ligno-cellulosic waste	Chemical stock for plastics, textiles etc.	F
6. <u>Water</u>	Paper mill effluent		P
	Coconut mill effluent		
	Rubber effluent	(recycle, reuse or irrigation water)	I
	Cassava effluent		I
	Sugar mill effluent		I
	Treated oil palm		I
	Oil effluent		M
	Distillery effluent		M

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/Note:

Note: The time base potential is designated as follows :

(i)	Present use	P
(ii)	Immediate potential	I (1 to 2 years)
(iii)	Mid-term potential	M (3 to 5 years)
(iv)	Future development	F (5 to 10 years)

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SOCIO-ECONOMIC ASPECTS OF AGRICULTURAL
AND
AGRO-INDUSTRIAL RESIDUE UTILIZATION

SOCIO-ECONOMIC ASPECTS OF AGRICULTURAL

AND

AGRO-INDUSTRIAL RESIDUE UTILIZATION

Note by the ESCAP secretariat*

1. In most of the member countries of ESCAP, the agricultural sector is generally responsible for the early growth and expansion of the economy. It is there that residues and wastes first accumulate. However, due to the agricultural sector's wide area of productive activity, planners and politicians generally overlook the implications of such residue production and accumulation for the agricultural environment, turning their attention instead to the concentrated residue or pollution problems of the industrial (and generally urban) sector. From the economic point of view, however, any residue accumulation is a potential cost to the environment and, in effect, reduces the over-all benefits of production to society.1/

2. There are several means at hand for reducing the costs of environmental pollution from residues derived from production. The most common is to reduce the pollution in residues by introducing the technology to do so. In this case we can speak of control costs which reduce the threat of pollution to the environment and, hence, increase over-all social benefits.

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* This paper was prepared by John C. Williams, Agriculture Division, ESCAP Secretariat. Reference AD/WAAIRU/6, 7 December 1979.

1/ The basic theory involved in the economic assessment of accumulation of residues is that the environment has a limited capacity to assimilate pollution. When the critical limit of assimilation is surpassed, environmental deterioration is created which has many destructive consequences for the ecological system, including the ultimate reduction of production. If these assimilative limits and the relationship between the ecological system and the production of residues were known, the costs to the pollution could be defined. See D.W. Pearce, Environmental Economics (London, Longman, 1976) chaps. 2 and 3.

3. Another method of reducing residue production and accumulation is to make use of a residue in a separate production process. This method will, again, reduce potentially polluting residues and hence the threat to the environment from its accumulation over time, the result of which is to increase the benefit of production to society.2/ In this case the use of a residue from a primary production process could potentially decrease the cost of primary production.

4. This paper discusses the socio-economic approach to the control and reduction of agricultural and agro-industrial residues and wastes. It looks at the problem foom two angles :

(1) From the angle of controlling the release of agricultural and agro-industrial residues into the environment. The reason for such concentration is that certain agro-industrial processes such as palm oil, rubber, alcohol production and tapioca processing have associated with them a large amount of waste water which must be treated in order to be used as a second-generation residue (recycled or irrigation water), or to be "safely" released into the environment. The socio-economic costs involved here are the control costs referred to earlier;

(2) From the angle of their use in a second-generation production process. Thus, one can speak of utilizing agricultural and agro-industrial residues for (a) renewable energy sources, (b) building materials, (c) animal feed, (d) fertilizers, and (e) chemical extracts. The use of these raw residues could be seen to potentially reduce the original production cost by extending the economic uses of the original agricultural product.

5. The paper is divided into three sections. The first section deals with treatment costs for residues, and is generally directed towards liquid residues. The second section discusses the economics of

/residue

2/ Care must be taken not to release a more unassimilative second generation residue into the environment by processing a first-generation residue. In such a case, the total benefit of production to society would be reduced.

residue utilization in terms of the five end-use categories mentioned above. The discussion concentrates on actual cases where residues are being utilized or where pilot or feasibility studies have been conducted. The concluding section reviews the current knowledge of the economics of residue utilization drawn from the previous sections and makes observations about the future concerns of residue utilization if social benefit is to exceed costs.

I POLLUTION TREATMENT COSTS

6. For liquid residues such as the effluents coming from tapioca starch, palm oil, rubber and sugarcane processing, the removal of pollutants is essential in order to protect the environment. The removal of pollutants in the liquid residue is considered to contribute to social benefit. The cost of environmental protection is the cost of the treatment plant, its operation and the social opportunity cost for the capital cost of the plant relative to its best alternative use. If all the elements in this cost/benefit calculation were known, a figure could be arrived at indicating the best use of funds relative to different methods of protecting the environment. Such sophistication, however, cannot be used here as the full range of social benefits is not precisely known. However, an assumption can be made that equal reductions of biological oxygen demand (BOD), chemical oxygen demand (COD) and suspended solids (SS) in waste water will equally enhance the benefit to society of the contributing production process. What would then be important is the treatment cost of different technologies and the cost of such treatment relative to the effluent standards (reduction in BOD, COD, SS) desired. Attention should also be given to the subsequent use, if any of the treated effluent, as such use could be use to offset, to varying degrees, the cost of treatment. This section reviews what is presently known about the costs of various treatments for the tapioca, rubber and oil palm industries. The discussion details the factors accounting for the costs, the increases in costs expected by increased effluent standards and the economic impact of treatment costs to society.

/7.

Some of the more common treatment methods for liquid residues are an anaerobic pond, a facultative oxidation pond, an aerated lagoon and a rotating biological drum filter.3/ The factors which effect the selection of one of these common treatment methods (or others available) are (a) data concerning the system's engineering design and pollution removal efficiencies, (b) capital and variable costs.

8. In terms of the removal of BOD and SS, the commonly accepted practice has been to use an anaerobic pond as a first-stage treatment for concentrated wastes. An anaerobic pond treating tapioca starch effluent has been shown to reduce BOD by 60 per cent and SS by 82 percent. For second-stage treatments, there seems to be considerable degree of substitution possible between a facultative oxidation pond, an aerated lagoon, a rotating biological drum filter and other technologies. A combination of first and second-stage treatments (aerated lagoon), has been shown to have total BOD removal efficiency of 94 per cent and this is vertified by other reports for other industries.4/ Problems exist, however, for decreasing nitrogen in rubber waste water, which is due to the addition of chemicals at the processing stage.5/

9. The main criteria for selection of a treatment technology are primarily based on costs. Table 1 presents data about various costs for first and second-stage treatment technologies for tapioca starch waste water for two factory sizes.

/Table 1

3/ These treatment methods have been described by N.C. Thanh in the workshop paper, "Pollution control and management of agro-industrial wastes".

4/ See U. Yòthin, Evaluation and Treatment of Wastes from the Tapioca Starch Industry, M. Eng. Thesis No. 836, Asian Institute of Technology, Bangkok, Thailand (1975); R.N. Muthurajah, and others, "Developments on the treatment of effluent from new process SMR factories", Proceedings, R.R.I.M. Planters' Conference, 1973; and C.K. John, and others, "Treatment of effluent from block rubber factories", Proceedings, R.R.I.M. Planters' Conference, 1974.

5/ For a discussion of this problem, see R.N. Muthurajah, op. cit.

Table 1 Treatment costs related to anaerobic ponds and second-stage treatment (aerated lagoon) for tapioca waste water for two factory capacities

Factory capacity	Cost of					
	Land Area (m^2)	Land (USD)	Excavation (USD)	Aerators/ concrete (USD)	Total capital for treatment (USD/yr)	Total operaion cost (USD/yr)
Anaerobic ponds (primary treatment)						
60 tonnes/day	3,800	650	6,250	-	6,900	480
8.4 "	530	250	875	-	1,125	240
Second-stage treatment						
60 tonnes/day	3,800	650	4,200	32,500	37,350	31,680
8.4 "	530	250	600	6,500	7,350	3,780

Source: U. Yothin, Evaluation and Treatment of Wastes from the Tapioca Starch Industry, M. Eng. Thesis No. 836, Asian Institute of Technology, Bangkok, Thailand (1975).

Note : Prices are for 1975 at the exchange rate of Baht 20.15 per one U.S. Dollar.

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10. The data in table 1 indicate that land and its excavation account for the most cost for anaerobic ponds. Thus the main considerations in the choice of a primary system would be the cost of land and its excavation. In this regard, if the land is restricted, then another treatment system might be considered. Land and its excavation are relatively less costly for secondary treatments. For the example in table 1, capital cost in the form of aerators and concrete is the highest cost. Variable costs (chemicals and electricity), have very much increased relative to capital costs. The data in table 1 suggest that selection of a secondary treatment system would be based on a trade-off between capital costs and land availability. If land was easily available, then a non-mechanized and land extensive facultative pond could be selected, otherwise an aeration system such as an aerated lagoon or even a more costly rotating biological drum filter (which uses only one quarter of the land spece as a pond or lagoon) would be used. It should be noted that capital costs for primary and secondary treatment of rubber waste water from a 20-tonne per day factory is US$25,974 in 1974 dollars.[6/] Variable costs were thought to be minimal, which suggests that land availability is a primary consideration for a rubber waste water treatment system.[7/]

11. Of more importance than the actual cost of the treatment system is the cost of the system relative to the total capital investment of the plant. One study has estimated this relationship for the tapioca industry.[8/] The study shows that for large capacity plants (60 tonnes

/per day

6/ The exchange rate used is 2.31 Malaysian dollars per one dollar.

7/ U. Yothin, *op. cit.*

8/ R.A. Luken, Economic Analusis of Alternative Effluent Guidelines for Tapioca Industry, Office of the National Environment Board, Thailand. (June 1976) per day) the treatment cost (capital and operating costs) as a percentage of total capital costs would be 0.8 per cent for a "low removal rate of organic material" and 4 per cent for a "high removal rate of organic material".9/ For a low-capacity factory (8.4 tonnes per day) the cost for a low removal treatment system would be 4.8 per cent of total capital costs. A high removal treatment system, however, would be 31 per cent of capital costs and if the factory had less capacity still, the percentage would increase. It can be expected that such a relationship between cost of a treatment system and total capital costs relative to a factory's production capacity would be generally true for industries other than that for tapioca. It should also be expected that with increased standards, costs of treatment relative to total capital cost would also increase.10/

12. Lack of empirical data prohibits a systematic discussion of the effects of the cost of waste water treatment for a national economy. However, a rough indication of the effects on the national economy can be given by considering the aggregate cost of such treatment. One can expect that with increasing standards for environment protection there will be corresponding increases in costs of production. Some of these costs will be transferred to the consumers and some absorbed by the industry. Fro the tapioca industry in Thailand, for instance it has

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9/ The study is not clear on the standards of the low and high removal rates. It suggests, however, that the low rates would be equivalent to those obtained by only an anaerobic pond (i.e. 60 per cent removal of BOD and 80 per cent removal of SS), while a high rate would be obtained by using both an anaerobic pond and second-stage treatment (i.e. 94 per cent removal of BOD and 82 per cent removal of SS).

10/ See, for instance, a recent report on regulating waste water loads for grouped discharges on a multiple reach stream (streamflow analysis). This report indicates that with increasing standards for dissolved oxygen concentration of the stream at all reaches, the cost of treatment would correspondingly, increase (B.N. Lohani and N.C. Thanh, "Probabilistic water quality control policies", Journal of the Environmental Engineering Division, ASCE (August 1979).

been estimated that price increases due to treatment costs can be expected to influence demand for products in a competitive system. To determine the effect of treatment costs on the industry it would be necessary to make an evaluation of such factors as market price fluctuations relative to price increases owing to treatment systems, price of substitutes, projected demand, and political considerations. Increases in production costs due to treatment costs would also have an effect on the internal rate of return to the factory. As discussed earlier, large capacity factories have less of a burden to bear in terms of the cost of treatment to total capital invested in the enterprise. It can be surmised that large capacity factories would have less of ar reduction in their internal rate of return than for smaller factories. This proves to be the case for the tapioca starch factories in Thailand, where increased standards from a "no-standard" base to a "high standard" base reduces the internal rate of return in large factories (60 tonnes per day) from 26 per cent to 20 per cent. These factories would, however, be economically viable. Small factories (8.4 tons per day or less) would have a reduction in the internal rate of return, under similarly increased standards, from 1 per cent to a negative figure. In this case, where the initial internal rate of return is very low, a factory would become economically unviable if it constructed a waste water treatment plant which conformed to a high standard of pollution removal.

13. With increasing effluent standards, one could expect economic dislocation in the sense that some marginal factories would close, unemployment would increase (perhaps only marginally) and investment in increasing a particular industry's capacity would decelerate. This is the price that can be expected to be paid for less environmental pollution, and must be weighed in terms of the social benefit that a less polluted environment gives to the nation in the short and in the long term. It should be noted that some of the cost of treatment can be offset by utilizing the treated waste water in some manner. There are examples of treated waste water used as fertilizers and animal feed. These examples will be discussed in the following section on residue utilization.

/II.

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II RESIDUE UTILIZATION

14. Any residue or waste can be used as a resource. This section will describe some of the agricultural and agro-industrial residues that are currently being sued as a resource, either in their raw state or in a processed form. Concentration is given to the economic use of agricultural and agro-industrial residues. In this regard, the discussion focuses on conditions and problems of supply and demand of the agricultural or agro-industrial residues. The cost of production relative to substitute products is also featured. The discussion proceeds by considering five potential end-uses for residues, i.e. renewable energy, construction materials and paper, food, fertilizers, and chemical extracts.

(A) Residues as renewable energy sources

15. There are several agricultural and agro-industrial residues within the crops studied here which can be converted into an energy source. The workshop paper on end-uses and technology has detailed the agricultural and agro-industrial residues which can be used as energy sources.[11/] It also identified two basic energy categories within which each residue would fall, that is, the residue could be used as an alcohol fuel or as a charcoal oil or gas substitute. These two categories will be dealt with separately in this section.

(a) Alcohol fuels

16. The basic residue for the production of alcohol fuels is molasses, a by-product from sugar mills. In most countries of the ESCAP region molasses is exported, the major exporters being Thailand and the Philippines and the minor ones, India and Pakistan.

/17.

11/ See B.H. Webb, "End-uses and technology for agricultural and agro-industrial residues", workshop paper.

17. With the increasing price of fossil fuels since 1973, the balance-of-payment import bill for virtually all countries in the ESCAP region has increased drastically, diverting capital from much-needed development projects. This factor has led many countries to seriously explore alternative sources of energy, and a few countries, such as Thailand and the Philippines, have decided to develop and implement an alcohol fuel programme.

18. The literature on alcohol fuels is vast, having been started before the turn of this century. Moreover, alcohol blended fuels (10 to 30 per cent alcohol in gasoline) are currently being successfully used in many countries the world over.[12/]

19. The current cost of producing ethanol (C_2H_5OH), the basic alcohol fuel for blending with gasoline, is fixed by technical production cost and cost of fuel stock (molasses and fuel for distillation). A representative cost for production of ethanol from molasses is given in table 2.

/Table 2

12/ Some countries currently using alcohol fuels are Brazil, France and Sweden.

Table 2 Production cost of 1 litre ethanol (95 per cent) in distilleries having different productivity in Thailand as of 1978

	Productivity per day (litres)				
	10,000	20,000	22,000	200,000	250,000
(in Thai baht)					
Molasses	2.61	2.31	2.62	2.74	2.46
Fuel and power	0.45	0.58	0.83	1.26	0.46
Chemicals and materials	0.09	0.07	0.35	0.10	0.45
Operation cost	0.70	0.15	0.27	0.15	0.18
Depreciation	0.20	0.40	0.70	0.40	0.90
Waste water treatment	-	-	-	-	0.29
Total cost (in baht)	4.05	3.51	4.78	4.65	4.79
(in US dollar)[a/]	0.20	0.17	0.24	0.23	0.23

Source: Jiraphol Sintunawa, Power Alcohol from Agricultural and Agro-industrial Products, M.S. Thesis, Mahidol University, Bangkok, Thailand, November 1978.

a/ The exchange rate is Baht 20.15 per one U.S. dollar.

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There are several features of table 2 which should be noted. First, the costs involved are actual costs, obtained from distilleries in Thailand which have different techniques, capital inputs and efficiencies of production. Owing to lack of standardization of the factories, efficiency of scale is not shown. Secondly, the cost of production is at 1978 prices and the price of the major input (molasses) is at the 1978 price of US$35 per ton. Thirdly, not all factories treat the waste water from the production process, which leads to considerable economic savings for some factories at the expense of a decrease in over-all social benefit through pollution of the environment. The treatment cost for distillery waste water is given in table 2 as 0.29 baht per litre of produced ethanol which would add to a total cost of US$3,598 per day of operation. This cost seems extremely high.13/ Moreover, nothing is known about the removal efficiency of BOD, SS and so forth for treatment as such cost; hence, the figure should remain speculative.

21. These observations aside, the average production cost for one litre of ethanol in 1978 was Baht 4.58 (US$ 0.23). It has been estimated that this average cost would decrease to Baht 4.02 (US$ 0.20) if production efficiency were increased.14/

22. Since 1978, the cost of molasses, the input having the highest cost for the production of ethanol, has increased to between US$57 (ex-factory cost) to US$80 (f.o.b.) per tonne which would increase the production costs of the product.15/ Selecting the low figure of US$57 as the most appropriate mid-1979 ex-factory cost for molasses, the

/correspon-
ding

13/ Jiraphol Sintunawa, Power Alcohol from Agricultural and Agro-industrial Products, M.S. Thesis, Mahidol University, Bangkok, Thailand, November 1978, p. 121. The exchange rate is Baht 20.15 to one U.S. dollar. A 300 tonne per day paper mill in Thailand stated that its treatment cost was Baht 47 per tonne of paper produced, or US$700 per day.

14/ Some methods for increasing production efficiency are to improve (a) efficiency of steam production, (b) strain of organisms which would ferment easily and give the highest yield of ethanol, (c) maximizing use of stillage, (d) using bagasse as fuel, (e) location of new plants. See Jiraphol Sintunawa, op. cit; chapter 6.

15/ The first figure (US$57 per ton) was obtained from interviews in Thailand and the second from interviews in the Philippines in August 1979.

corresponding average actual cost of ethyl alcohol production in 1979 (based on the 1978 survey) would be Baht 6.25 (US$0.31) per litre and the average cost, if efficiency were increased, would be Baht 5.30 (US$0.26) per litre. These 1979 costs of production figures have been corroborated by other independent studies and by investigations of the ESCAP/UNEP mission in August 1979. The comparative costs of production are given in table 3.

/Table 3.

Table 3. Ex-factory production costs of ethanol production from molasses and retail gasoline prices in two ESCAP member countries

Country		Factory Capacity (litres/day)	Ex-factory production cost per litre a/	Retail gasoline price per litre	Year of study
			b/ (US dollars)		
Thailand	(1)	250,000	฿4.79 (0.24)	฿ 4.98	Aug. 1978
Thailand	(2)	average 5 factories	฿6.25 (0.31)	฿ 7.84	1979
Thailand	(3)	average 5 factories	฿5.30 (0.26)	฿ 7.84	1979
Thailand	(4)	60,000	฿6.00 (0.30)	฿ 7.84	1979
Philippines	(5)	15,000-17,000	P1.60 (0.22)	-	1979

Sources: (1) Jiraphol Sintunawa (See source, table 2).

(2) Estimate (this paper) for actual production.

(3) Estimate (this paper) for efficient production.

(4) Export factory, Thailand.

(5) Canlubong Sugar Estate, Philippines.

a/ The ex-factory production cost per litre does not include excise duty, blending costs, transportation costs and profit.

b/ The exchange rate is Baht 20.15 and P 7.38 per one U.S. dollar.

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23. The main criterion for the economic viability of ethanol production from the molasses by-product is the cost of the substitute product, gasoline.16/ Very little data are available on this topic in the ESCAP region. However, table 3 suggests that ex-factory ethanol production costs are becoming more competitive with retail gasoline prices as petroleum prices continue to increase. The same is probably true for the Philippines example. It should be recalled, however, that the ethanol price in table 3 is an ex-factory cost of production, to which cost of management, water treatment cost, transport costs, profit margins and so forth must be added in order to make it equivalent to the retail price of gasoline. With this in mind, a feasibility study should be conducted before commitment to an alcohol fuel programme is fixed with a view to considering several factors which affect production costs and factory operation. These factors include (i) the supply of molasses and its seasonability, (ii) cost of collection of inputs, (iii) factory scale and engineering possibilities (construction of new or auxiliary factories), (iv) alternative use of capital (opportunity costs), (v) impact on the regional environment (employment, rural development), (vi) impact on the stabilization of crop prices, (vii) cost of importation of capital goods and expertise, (viii) effect on balance of payments, and (ix) market demand. Special attention should be paid to the role of government in setting the ethanol price for blending with gasoline. In this regard, the use of excise taxes (which are currently excessively high for alcohol production) must be reviewed. Consideration must also be given to the role the Government can play in developing an alcohol fuel programme with all the implications that this has for regulating policy and national legislation. Finally, the feasibility study should consider the technical

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16/ From the view point of economics, the effect of the ethanol and gasoline blend on the environment must be evaluated as a social cost. A wealth of literature has discussed the environmental implications of emissions from an ethanol and gasoline blend relative to gasoline emissions. The literature concludes that the fuel alcohol emissions are no worse than those of gasoline alone and may even have less pollutants in comparison with gasoline when the combustion engine is properly adjusted for alcohol fuel utilization. There is also no evidence that a 15 to 20 per cent ethyl alcohol blend harms current combustion engines. See Alcohol Fuels, a conference held at the Sebel Town House, Sydney, Australia, 9-11 August 1978, organized by the Institution of Chemical Engineers, N.S.W. Group C/Department of Chemical Engineering, University of Sydney, Australia 2006.

and economic options of designing an ethanol factory from inputs other than molasses or in combination with molasses. There are, of course, many alternatives in producing ethanol and hence many substitutes and combinations for the production process. Of special interest to the countries in the ESCAP region, however, is the potentialities of using sugarcane or cassava, or a combination of both, in the production process.

24. A few studies have estimated that costs of production for ethanol from sugarcane, cassava, and their combination in various factory types. One such study suggested that there was a distinct economic advantage in producing ethanol in existing sugarcane factories from raw cane as there would be a savings in capital costs and depreciation relative to constructing new factories.17/ The cost of producing the ethanol in this factory type was estimated at US$0.14 per litre. Attaching a cassava processing line to the existing sugar mill would reduce production costs further owing to reducing fuel costs (bagasse and cassava stems could be used for this purpose), and reduced equipment costs for boiler and subsequent services. The cost of producing ethanol in the integrated sugarcane-cassava factory is estimated to be US$0.8 per litre. It therefore makes economic sense to investigate the possibility of using a combined sugarcane (or molasses) and cassava factory. Such a factory would also lead to greater stability of input price and supply and may contribute to the optimum use of land near the factory site.

(b) Charcoal, gas and oil substitutes

25. An ESCAP/UNEP mission in August-September 1979 discovered many examples where agricultural and agro-industrial residues were used as fuel substitutes. These examples relate to the use of rice husk and bagasse as fuel sources and coconut husk as charcoal. In Pakistan, rice husk is currently being used to dry bricks. It was reported that the use of rice husk as a fuel was so successful that now Pakistan-made bricks could compete on the market with India-made bricks. In Thailand, rice husk is

/used

17/ T.A. Bull, and others, "Potential for multi crop processing within the sugar industry", Alcohol Fuels, op. cit.

used as a fuel for generating steam to power a few rice mills. The savings for using rice husk as a fuel were reported to be Baht 0.08 per kilo of rice or one per cent of total value of a 100 kilo bag of rice. In the Philippines, rice husk is used to supply 1,900 kW of electric power to an adjacent rice mill and to a small town in Mindanao. The power plant's supply of rice husk comes from the adjacent rice mill which has a capacity of 25 tonnes paddy per day. The power plant itself was established in 1968 under a loan from IBRD and the Philippines Development Bank. The National Grains Authority (NGA) of the Philippines took over control of the former privately controlled enterprise in 1977 after it ran into financial difficulties. Presently, NGA is still supplying power to consumers at the rate of P 0.12 per kW hour. It is not clear, however, that the current price of electricity is sufficient to cover costs. Neither is it clear when happens to the residue from burning the rice husk.

26. Another widely used agricultural residue for fuel is bagasse, a residue which has traditionally been used to offset fuel costs in sugar mills. While there was a trend away from the use of bagasse as a fuel in the early 1970s, a reversal of this trend seems to have set in owing to the high costs of fossil fuels.

27. A processed fuel derived from agricultural residues is charcoal. Charcoal can be processed from virtually any residue, but not all residues can produce good charcoal.[18/] Coconut shell and husk, for instance, is used to manufacture charcoal in easily constructed pits or in more complex, but easily constructed burners. In the Philippines the bulk of exports of charcoal from coconut shell goes to Japan (about 93 metric tonnes exported between 1970 and 1976). The price behaviour of exported charcoal has been erratic since the 1970s, with a high point reached in

/1974

18/ Good charcoal is based upon its heating value (BTU) and this varies tremendously between substances which can be carbonized. See also B.H. Webb, op. cit.

1974 of about US$ 138 per tonne (f.o.b., Manila), which has drastically declined since.[19/] It should be mentioned that as economic development progress in the member countries of the ESCAP region, there is a tendency to move from agricultural and agro-industrial residues as a fuel to more convenient fuel sources. The case of the Republic of Korea is typical. A traditional fuel for cooking in the rural areas of that country was rice husk. But with increased incomes, the demand for fossil-based cooking fuels (kerosene, butane) has so increased that rice husk is currently abandoned as a fuel source. It is unlikely that this situation can be reversed, even with increased costs for fossil fuels, owing to the convenience of cooking that fossil fuel brings.

28. The aforementioned instances of traditional and current uses of agricultural raw materials and fuels sources lack a considerable amount of economic analysis. In essence, the economics of agricultural and agro-industrial residues as fuel sources are not well researched. There are, however, a few provocative examples of technologies which could be used to transform agricultural residues into fuel sources which have associated with them some economic analysis. The best example in this category focuses on the manufacture of charcoal, oil and gas through pyrolytic conversion by the thermal degradation of ligno-cellulosic materials (rice hulls, bagasse, rice straw, etc.)[20/] An economic analysis of the viability of using rice hulls as a supply source has been carried out in the case of Indonesia.[21/] The primary reason behind

/selecting

19/ Data from <u>The Philippine Coconut Industry</u>, pamphlet prepared by Market Promotions Division, Philippine Coconut Industry, no date, p. 22. In 1976 the price of shell charcoal had declined to about US$ 94 per tonne (f.o.b. Manila).

20/ See also B.H. Webb, *op. cit.*

21/ <u>Pyrolytic Çonversion of Agricultural and Forestry Wastes to Alternative Energy Sources in Indonesia; a Feasibility Study</u>, Economic Development Laboratory, EES, Georgia Institute of Technology, Atlanta, Ga. 30332; and <u>Applying Pyrolytic Conversion to Indonesia</u>, USAID/Indonesia Science and Technology Office, Jakarta.

selecting rice hulls as the input source is the large number of local rice mills (some 1,444 large mills with a capacity of over one tonne per day, and 28,059 small mills) which could effect a reasonable supply of rice hulls for the conversion process.22/

29. The estimated costs and returns of a moderately capital-intensive pyrolytic conversion plant, which is used to capacity and which has a dryer attached, is shown in table 4.

/Table 4.

22/ See Pyrolytic Conversion ...., op. cit., annex II, table 1, p. 11. The total amount of husks generated is 5.66 million metric tonnes per annum in 1975.

Table 4 Estimated cost and return of moderately capital-intensive pyrolytic conversion plant with attached IRRI dryer

(Capacity: 0.25 tonnes charcoal and 0.15 tons oil per day)

	Rupiahs	U.S. dollars
Capital costs		
Production components	800,000	1,951
Building and hall storage	250,000	610
Contingency	100,000	244
Working capital	250,000	610
Total capital costs	1,400,000	3,415
Operating costs (per year)[a/]		
Labour	420,000[b/]	1,024
Management overhead and maintenance	150,000	366
Debt service	253,400[c/]	618
Total operating cost	823,400	2,008
Estimated returns (per year)		
Charcoal	450,000	1,098
Oils	237,600	579
Drying service	360,000[d/]	878
Total estimated returns	1,047,600	2,555
Profit before taxes (estimated returns-operating cost)	224,200	547

Source: Pyrolytic Conversion, op. cit., annex II, pp. 11-20

a/ Based, on a 150-day operation per year in order to follow normal price mill operation in Indonesia.

b/ Three shifts of two persons per day paid at Rp 400 per day.

c/ Debt service includes both interest and principal for the total capital requirements, based on a 10 year term at 12.5% annual interest rate.

d/ For drying wet paddy brought in by formers.

Note : The exchange rate used is 410 rupiahs per U.S. dollar.

/30.

30. According to the estimates in table 4, the return on investment would be 16 per cent, with a payback time of some 6.25 years. In this regard, a comparison between the returns on investment between pyrolytic conversion plants and rice mills is quite favourable. That is, for rice mills which produce one ton of rice husk per day, the income is typically in the range of 400,000 to 600,000 rupiahs per year (US$ 975 to 1,463) and the return on investment is approximately 15 to 16 per cent.

31. It should be noted that table 4 is based on certain underlying assumptions. On the supply side, for instance, it is assumed that one ton of hulls per day would be available for 150 days of operation, and their cost and transport cost would be zero. In effect this assumption implies that the rice mill and the pyrolytic conversion plant would be an integrated factory unit which provides milling services, drying services and consumer products (charcoal and oils). If the integration is not established the cost of operations would increase owing to increased input costs (rice hulls) and revenue would be decreased owing to a lack of demand for drying services which to be used must be located adjacent to a rice mill.

32. From the demand side, the assumed price of charcoal is that of the market price for loose charcoal (about 33 rupiah (US$ 0.8) per kilogram) which is less suitable for cooking and heating than the higher priced lump charcoal produced from a mound or kiln.[23/] More importantly, there is a declining demand for charcoal in Indonesia, which would mean a decrease in price overtime unless export potential of the product is realized. The price of char oil is estimated to be proportionate to its heating value relative to the heating value of its closest substitute, kerosene.[24/]

/However,

23/ Loose charcoal is best used as a boiler fuel, but if so used in Indonesia it must compete with domestic subsidized fuel oil.

24/ The char oil has a heating value equivalent to two thirds that of kerosene. The price is thus estimated to be 10.56 rupiahs.

However, there are disadvantages in char oil which are not evident for kerosene, that is, in its initially produced form char oil has a pungent odour and is mildly corrosive. Moreover, new designs of lamps and cooking stoves must be introduced to use char oil effectively. These disadvantages will be likely to reduce the demand (and price) of char oil below the equivalent heating value of its nearest substitute and reduce returns in the example of table 1. A market survey would therefore be a first step before undertaking investment in a pyrolytic conversion plant.

B. Residues as building materials

33. Agricultural and agro-industrial residues can be used for various types of building materials. In this section focus is turned to those residues for building materials and building material technologies which are in progress or have been developed to pilot-scale operation so that an economic analysis can be made. Two technologies are, therefore, considered: brick-making and particle board manufacture. The section will close by discussing the special case of coconut stem utilization.[25/]

34. Rice husk ash has been tested for use with lime and cement for use in brick making.[26/] The compression strength of various rice husk ash mixed bricks and their relative costs are given in table 5.

/Table 5

25/ The use of residues for paper making should also be featured in this section. However, very little economic information concerning their use for this purpose is available. One report suggests that bagasse can be mixed with other pulping materials at a cost above that of waste paper by 52 per cent, but by 6 and 14 per cent below that of short and long white pulp, respectively. (See Suchart Nak-on, Specific Industrial Economics Report: Pulp and Paper Industry, Ministry of Industry, Thailand 1978). The problem of using bagasse as a pulping material is its unavailability due to its use as fuel.

26/ The Forest Products Research and Industries Development Commission (FORPRIDECOM) of the Philippines has tested Coconut Coir Dust as a brick-making substitute. The prelimenary tests indicate that there is a high positive correlation between maximum load and the weight/volume ratio of coir-dust to the fabricated bricks (Personal note, FORPRIDECOM, 1979).

Table 5 Mix proportions and relative costs of cement, lime, rice husk ash to sand and the comparative compressive strength of the resultant blocks

(Cost in baht)

Mix proportions	(Cement + Lime + Rice Husk Ash): Sand										
		(1.0+0+0): 2.75		(0.60+0+0.40): 2.75		(0.50+0+0): 2.75		(0.15+0.283+0.567): 2.75		(0.10+0.30+0.60): 2.75	
Mix components	Relative cost per kg.	Quantity (kg)	Relative cost	Quantity (kg)	Relative cost	Quantity (kg)	Relative cost	Quantity (kg)	Relative cost	Quantity (kg)	Relative cost
Sand	1.00	4.776	4.78	4.583	4.58	4.400	4.40	4.033	4.03	4.033	4.03
Cement	23.7	1.733	41.07	1.00	23.70	0.800	18.96	0.219	5.19	0.146	3.46
Lime	19.9	-	-	-	-	-	-	0.415	8.26	0.439	8.74
Rice husk ash	7.7	-	-	0.666	5.13	0.800	6.16	0.831	6.40	0.879	6.79
Sodium aluminate	410.0	-	-	0.016	6.56	0.016	6.56	0.018	7.38	0.018	7.30
Total relative cost	Baht US$		45.89 2.28		39.97 1.98		36.08 1.79		31.26 1.55		30.38 1.51
Compressive strength (MPa) (at 7 and 28 days) a/		In excess of 5.50 for individual unit b/		3.49 and 5.32		3.45 and 5.08		2.33 and 3.87		1.94 and 3.85	

Source: David J. Cook, and others, Rice Husk Ash - Lime - Cement Mixes for Use in Masonry Units, (Bangkok, Thailand Asian Institute of Technology, Paper VF/278, 1976).

a/ Average of five tests in million pascal (MPa).

b/ This figure is equivalent ot the American Standard Test Material (ASTM) requirements for loading-bearing masonry. The ASTM requirement for non load-bearing masonry is 3.45 MPa.

Note : The exchange rate is Baht 20.15 per one U.S. dollar. The costs are in 1976 prices.

35. In terms of strength, it appears that rice husk ash could constitute up to 60 per cent of the total aggregate mix to produce bricks that would satisfy the requirements for non load-bearing masonry. The requirements for load-bearing masonry could only be met after moist curing of the brick beyond three days or under low-pressure steam curing. It is, therefore, advised from the technical point of view, to use the rice husk ash brick only for non load-bearing masonry.

36. The relative costs of the several rice husk ash mixtures in comparison with a sand-cement mixture are also presented in table 6. The data indicate that the more rice husk ash used in the mixture (at a cost of 32 per cent less than the cost of ordinary cement based on 1976 Bangkok prices), the cheaper the cost of the brick. However, the more rice husk ash used the less the compressive strength of the brick. All bricks, after curing for 28 days, can pass the ASTM requirement for non load-bearing maxonry, but only the 60 to 40 and 50 to 50 mixtures of cement to rice husk can pass the non load-bearing masonry requirement after seven days of drying. Finally, it should be noted that the cement-sand mixture used in the example gives a brick superior to the specifications of the rice husk ash brick and hence a brick more valued than the rice husk ash brick. These results suggest that a greater amount of economic analysis needs to be conducted before a conclusion is reached on rice husk ash brick viability. From the example in table 5, however, it appears that a future conclusion may be that rice husk ash brick is only economically viable for non load-bearing bricks.

(ii) Particle boards

37. Many types of agricultural residues and two technologies can be used to make particle boards.[27/] The common technology adopted is the

/use of

27/ A special type of board using rice straw (18 per cent of total production cost) as an input is known as "strawmit" compressed board. One such factory has been established in Thailand since 1967, but due to demand constraints it only functions at 28.9 per cent of capacity. The high point in production was in 1974 (58,832 m^2); the production in 1977 declined to 43,380 m^2. The problems of the industry are unavailability of raw material (rice straw having 20 per cent moisture content), and competing products. (See Laksana Tantiyamart, Special Industrial Economics Report: Compressed Straw Industry, Ministry of Industry, Thailand, 1977).

use of a binding resin to create the board. Rice husk particle boards are often claimed to be superior to plywood and other wood-based and residue-based particle boards as they are water-and termite-resistant and are a fire retardant. They also have a higher tensile strength (at specific gravity of 0.60, 5/8 in thick) and are reported to be amenable to all wood work processes such as sawing, nailing, drilling, and screwing.28/

38. The rice husk particle board produced by the resin-binding process is also claimed to make use of a simpler production process than that for the production of wood-based chip board, which decreases its production cost by some 25 to 30 per cent. However, it is only the "external grade" or "water-resistant" boards made from the high cost phenol-formaldehyde resin which can be successfully combined with rice husk. Even then it is claimed that the rice husk board is 15 to 20 per cent cheaper than the "exterior grade" of wood-based particle boards and is competitive with the "interior grade". The investment on a 20 tonne per day rice husk particle board factory is estimated to be US$ 2.06 million in 1979 dollars, with an expected discounted rate of return on investment of 25 per cent per year (payback period of 3½ years with net earnings of US$ 1.37 million in five years).29/

39. A second technology for using agricultural residues as building materials is called the "thermodyn process" which can convert all vegetal materials with ligneous and cellulosic components into floor tiles, wall-

/ board,

28/ A.A. Pablo and J.B. Sequerra, Development of Particle Board in a Pilot-Plant and Commercial Scale Using Agricultural Wastes as the Raw Materials (Undepithed Sugarcane Bagasse), FORPRIDECOM. In the series of experiments of this study no board passed the tensile strength requirement set by the Australian Standard Specifications. No economic data are available; although the study shows that the cost would be dependent on (i) the cost of resin (which increases strength and reduces thickness swell and water absorption properties) and on (ii) the cost of machinery to further reduce the size and shape of the undepithed bagasse.

29/ All financial data are from Investment Prospectus for the Establishment of a Rice Husk Board Manufacturing Plant (20 tons per day), Cortech wall-board Asia limited, Philippine Branch Office, Makati, Metro Manila, 2 January 1979).

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board, furniture and sanitary equipment. The technology claims to be not based on synthetic bonding substances (resins).

> "The originality of the invention lies in the discovery that ligneous and cellulosic components, when processed without bonding substances, in specially sealed molds, under high pressures (250-300 kg/cm^2) and high temperatures (140-180°C), then cooled without releasing gases or pressure, would polymerize in contact with carbonyls and resin components existent in all vegetal material. Such components, due to the combined action of pressure and heat, become gaseous and contribute to the molecular transformation in the course of a chemical chain reaction taking place inside the molds."30/

There are two advantages of this process: (a) a possible reduction of production costs for painting and lacquering by 35 per cent due to the simultaneous decoration of the process and (b) a superior quality of the finished product which is water-resistant (non-porous), practically unbreakable, and exhibits relatively high screw pull extraction.

40. It is reported that the most profitable fabrications for the process are pieces which are expensive because of the multiple operations required or the sort of material used, such as decorated formwood or particle panels with decorative revetment. It is claimed that the thermodyn product would also be competitive with furniture (kitchen panels, shelves, table tops, school desks, etc.). A market survey, however, would be indispensable before investment as the aforementioned conditions of profitability are based on European experience. The cost and profit margin of the technology would be dependent on such a market survey which would also need to determine the agricultural raw material supply conditions. A very sketchy idea of the net profit margin for a factory working three shifts are given in one report to be approximately 20 per cent per

/annum

30/ This quotation and all financial data comes from Thermodyn Process, rotech services, pte. ltd. unit, Singapore, Mimeograph dated 31 July 1979.

annum. The report goes on to say that "previous studies made indicate that investments (approximately .75 million U.S. dollars) and operational cash funds are totally reimbursed within three to five years, depending on the products and markets".31/ The impression is that these studies were based upon factories which did not use widely scattered and bulky agricultural raw materials as the production input.

(iii) Coconut stem: A special case

41. In many of the coconut-growing countries, attention has recently turned to programmes for replanting schemes to replace the aged coconut palm. The Philippines, for instance, has developed a programme for implementation which would replant 60,000 ha of coconut land per year. This in essence would mean some 143 million cubic feet of coconut stems available for use per year, starting in 1980. For the South Pacific countries, the extent of coconut resources (the over-mature coconut tree) which could be used for stems is 31 per cent of the total area planted in coconut palms (.46 million ha).32/

42. In some Pacific island countries, coconut stems have been used sporadically for construction purposes for years. However, with the soon-to-be-implemented coconut replanting programmes, the contemporary period is the first time that a large volume of coconut stems have been available for utilization. Given the newness of the product on the market, it is rather difficult to determine how great demand for the product and the amount of investment enterpreneurs are willing to undertake for producing and marketing coconut stem products.33/

/43.

31/ Thermodyn Process, op. cit., appendix.

32/ Data from Cook Islands, Fiji, Kiribati, New Caledonia, New Hebrides, Niue, Solomon Islands, Tonga, Tuvalu and Samoa. See Coconut Stem Utilization Seminar, Tonga, October 1976, Ministry of Foreign Affairs, Wellington, New Zealand, 1-77, p. 13.

33/ Certain firms have been established for commercial enterprises, probably the most notable of which is Cocostem Investigation Unit (New Zealand) which specializes in parquet flooring from coconut wood.

43. On the scientific side there is a wealth of information about the structure and possible use of the coconut stem as a building material.[34] For instance, it is well known that coconut has a dense outer layer and a very much less dense core. Density is, moreover, different at the same height from tree to tree in the same population. The wood has very hard, thickwalled fibres and as a result soon blunts conventional steel saws when sawmilled. The wood seems to be unusually hygroscopic, generally needs preservation treatment, and the core wood sometimes suffers structural collapse. In terms of strength, the high-density wood is very strong and does not suffer from degrading defects, but the low-density wood is extremely weak, hence a separation of the two woods is essential if the material is to be used for a designed structure. These structural properties of coconut wood suggest that processing costs would be higher than woods currently in use. This implies that coconut wood should be used as a substitute for expensive wood products (parquet flooring) where maximum profit can be obtained. Besides expensive wood products there are possibilities to use coconut wood for poles and posts (when treated),[35] furniture, particle board,[36] laminated beams, charcoal, pulp and paper etc. So far no policy has evolved on the use of coconut stems, although alternatives are known. It would seem that such indecision is occasioned by the little knowledge that exists about the market conditions for a potentially inferior wood product which has high processing costs.

44. There is much scope for reducing some of the uncertainty surrounding the processing costs and use of coconut wood by improving statistical records for the coconut resource, increasing experience in

/methods

34/ See Coconut Stem Utilization Seminar, op. cit.

35/ See E.P. Espiloy, "Coconut trunk for power and telecommunication poles", FORPRIDECOM Technical Notes, No. 182, Laguna, Philippines.

36/ See A.A. Pablo, and others, "Coconut trunk and wood/ coconut trunk particle mixtures", NSDB Technology Journal, vol. II, No. 2, Manila, Philippines.

methods and means of planting and harvesting the logs, and investigating market potential vis-a-vis the structural characteristics of the logs. Without such knowledge, which would decrease the risk of utilizing coconut stems, the stems may lie to rot after being felled, which would increase the chances of pest infection of new plantations and decrease the social benefits of replanting schemes.37/

C. Residues as feedstuffs

45. Of the crop residues under review, virtually all are currently being used as feedstuff or are currently undergoing investigation concerning their potential utilization as an animal or poultry feed. In this section a number of the crop residues which are considered non-traditional feedstuffs and which have associated with them estimates of their economic utility will be reviewed. These non-traditional feedstuffs include molasses-nitrogen mixtures, molasses-bagasse mixtures, protein feed from cassava foliage, and feedstuffs from oil palm plants.38/

(a) Molasses-nitrogen mixture

46. Molasses has for years been used in small quantities as an additive in feedstuffs in order to increase feedstuff palatability. A novel use of molasses, however, is to make it the principal ingredient of a feedstuff. One such feedstuff, designed for maximum molasses intake, is a low non-protein nigrogen liquid supplement composed, at the 12 per cent crude protein equivalent, of 87 per cent molasses, 1.7 per cent

/urea,

37/ Much of the material for this section comes from Coconut Stem Utilization Seminar, op. cit. and F.N. Tamolang, Utilization of coconut timber paper presented at the Symposium on the occasion of the U.P. Foresting Alumni Association's Annual Homecoming and Reunion on 13 April 1978.

38/ The traditional feedstuffs such as rice bran and straw, maize stalks, copra cake, sugarcane filter press mud, sugarcane tops, cassava products and so forth are not covered in this section as they are already being used by farmers as feedstuffs. A few residues, such as rubber seed oil cake and rubber factory affluents, have been fed to non-monogastric animals, but have proved not to be very palatab_e or otherwise unacceptable in their present form. Finally rice bran oil is not discussed as no economic study on it as a product was found.

urea, 1.5 per cent sodium chloride, 2 per cent diammonium phosphate, 0.5 per cent ammonium sulphate, a trace of vitamin A and D (premix) and 7.3 per cent water.[39/] The cost of the supplement would be based, in large part, on the price of molasses. In areas where no market for molasses exists, due to regulation or bottle-necks, the cost would be negligible. For Pakistan's sugar refining areas, for instance, the cost of the aforementioned feedstuff supplement would be PRs. 82.05 (US$ 8.26) per ton (at zero price for molasses) which is much lower than other feedstuffs having less protein content. With an increased price for molasses, however, the price of the supplement would increase. If for example, the cost of molasses rose in Pakistan to between PRs. 400 and 440 (US$ 40.28 and 44.31) per tonne the price of the supplement would rise to approximately the cost of alternative feeds on a dry matter (DM) basis.[40/]

47. The economic use of a potential feed is more complicated than comparing the cost of a feed to its immediate substitutes, although this can give a first approximatation of its economic use. Such use of potential feedstuff also depends on (i) its physiological effect on animals or poultry (rate of digestible energy, toxic effects, etc.), (ii) its market, (iii) the price of animal or poultry products, and (iv) weight gain of the animal on the diet. A high diet of molasses, for instance, must be accompanied by other foods or else depression of appetite is likely to occur. Moreover, a high molasses diet may cause toxic effects. It is essential, therefore, that good management must accompany high molasses diets.

48. Three other problems constrain the use of residues such as molasses as a feedstuff. It is unlikely that a residue can be transported for distances without unduly affecting the economic competitive-

/ness

39/ G.E. Lines, Z.O. Muller and H.L. Rollinson Sugar mill feedlot producing premium beef for the Lahore market, working paper for UNDP/FAO Product Co-ordinated National Programme for Livestock and Dairy Development, July 1979.

40/ The cost of the supplement when molasses in PRs 400 per tonne is, for instance, PRs 504 (US$ 51) which compares unfavourably with NH_3 treated straw in the G.E. Lines, and others, study, *op. cit.*

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ness of its feedstuff product. This implies that a feedlot must be nearby or must be constructed near the source of the residue. A second problem concerns the expected weight gain for animals or poultry in the Asian and the Pacific region. Most scientific studies of weight gain to date are based upon weight gains for temperate climates and for temperate climate breeds. The evidence of weight gains from various feeds in the tropical areas are scanty and are confined to only a small proportion of the life-cycle of the animal or poultry.[41/] This condition implies that at least a pilot study must be conducted before investment in a feedstuff enterprise is considered. Finally, many meat and egg markets are government-controlled; these controls are generally set for consumers, not producers, and tend to make enterpreneurs very conservative in their behaviour in using new products. These basic conditions of non-traditional feedstuff development apply to the other non-traditional feedstuffs discussed in this section and will be re-emphasized at its conclusion.

(b) Bagasse-molasses mixtures

49. Many studies have been completed on bagasse as a feedstuff. In general bagasse can be used as a substitute for other roughage. In areas where forages are short, coarsely ground bagasse has been used at levels between 10 to 20 per cent with other feedstuff. For beef cattle, bagasse pith which is composed of short fibres, has been used up to 27.5 per cent

/before

41/ R.I. Hutagalung, "Non-traditional feeding stuffs for livestock", Symposium on Feedingstuffs for Livestock, 17-19 October 1977, National University of Malaysia, Kuala Lumpur, Malaysia. On the findings for residue feedstuffs for livestock, the author states, "most of these data are from short-term feeding experiments, providing information mainly only on proximate composition and the performance of animals at the growing and finishing stage of their development. There is obviously a need to undertake life-cycle feeding studies to cover not only weight gains and feed efficiency of the animals, but also the safety evaluation of these (residue) feedingstuffs, in view of possible health hazards from consuming the final products." (p. 18) before cattle production declined. It has also been found that a mixture of bagasse and molasses increases the palatability of the former.42/ One study recommends the use of a bagasse pith (treated with NH_3) - molasses mixture at the dry matter (DM) ratio of 62.3 to 21 per cent, the remainder of the mixture being (in percentage) urea (1.47), DAP (0.49), NaCl (0.49), limestone (0.34) and flowers of sulphur (0.15).43/ Table 6 presents data concerning comparisons between the treated bagasse pith forage pellets and traditional roughage.

/Table 6

42/ Data taken from Bo Gohl, Tropical Feeds (FAO, Rome, 1975), p. 444.

43/ Data from Z.O. Muller and D.H.L. Rollinson, "Production of forage pellets from sugar mill by-products and wastes, working paper for FAO/UNDP Project Co-ordinated National Programme for Livestock and Dairy Development, July 1979. A second formula is also recommended using a high quantity of bagasse pith treated with NH_3 on a DM basis. That is treated pith 79.25 per cent with molasses (6.4), urea (0.98), DAP (0.49), NACI (0.47), limestone (0.49) magnesium oxide (0.24), flowers of sulphur (0.20).

Table 6 Comparison of forage pellets (treated bagasse pith and molasses mixture) and traditional roughage

Item	Nutrients on DM basis			Raw material cost PRs/ton (US$/ton)
	Crude Protein	Net energy (Mcal/kg)		
		Maintenance	Location	
Forage pellets	10.46	1.26	1.30	319.64 (32.19)
Maize[a/]	5.90	1.26	1.32	-
Oat, hay	9.20	1.31	1.37	-
Sugarcane tops (green)	6.50	1.27	1.29	-

Source: Z.O. Muller, and D.H.L. Rollinson, "Production of forage pellets from sugar mill by-products and wastes", (July 1979), table 8.

Note : The exchange rate is PRs. 9.93 per one U.S. dollar. The costs are in 1979 prices.

a/ Stover, sun-dried.

/50.

50. The data in table 6 indicate that the forage pellets compare favourably with other roughages in terms of nutrients on a DM basis. Moreover, the cost of raw materials in Pakistan (1979) is only PRs. 319.64 (US$ 32.19) per tonne. It is recommended that the forage pellets be sold for PRs 750 (US$ 75.53) per tonne, a figure derived from cost-benefit studies of plant production. The recommended figure is claimed to be cheaper than traditional forage and roughage in urban areas of Sind province, Pakistan.

51. To achieve economic viability, the forage pellets should be produced at an integrated sugar mill and cattle feed manufacturing complex. The estimated output of the plant would be 50 tonnes of forage pellets per day which would need an initial investment of PRs 9.89 (US$ 995,972) million. The internal return (based on a product sold at PRs 750 per tonne) would be 22.4 per cent and the payback period would be 5.8 years.[44/] A basic problem is marketing of the pellets. The report assumes that the market would be urban-based dairy colonies (Landi Dairy Colony near Karachi; a dairy colony near Hyderabad) and herds of dairy cattle which are near urban centres. No formal marketing studies, however, were made nor were pilot projects constructed to test potential production problems or feeding problems to cattle.

(c) Protein feed from cassava foliage

52. Harvesting cassava leaves to produce a protein feed has been reported upon by several sources.[45/] The concern over cassava leaves as a protein source comes from data which indicate that upon processing (cooking, pressing and evaporation) cassava leaves produce a concentrate containing 45 to 50 per cent protein. A very high protein meal can also be produced which can be further processed through mixing the meal with the liquid concentrate to produce animal feed which contains 29.25 to 32.5 per cent protein. The cost of the cassava foliage meal is estimated to be US$ 150 per tonne (including administrative expenses and

/depreciation).

44/ All data from Z.O. Muller and D.H.L. Rollinson, op. cit.

45/ See B.H. Webb, and others, "Protein feed from cassava foliage", paper presented at the Regional Conference on Technology for Rural Development 24-29 April 1978, Kuala Lumpur, Malaysia and cited references.

depreciation). It is estimated that on an accounting basis, a 2,800 ha estate in Malaysia producing 31.5 tonnes of dried cassava forage per ha per year would have a rate of return on investment, after tax, of 21 per cent. The investment would be about M$ 43 (US$ 19.54) million or M$ 15,360 (US$ 6,982) per ha (1978 prices), which is about 1.55 times that of oil palm estate development.46/ However, the breakeven point for investment in the cassava forage estate is reached in 4.5 years rather than 10 years, as is the case for an oil palm estate.

(d) Palm oil by-products as feedstuffs

53. Several feeding trials have been conducted,47/ using palm oil effluents and by-products for cattle or buffaloes. One report estimates the economic potentialities of using a maximum amount of palm oil effluents and by-products.48/ The feed formula and its reported live weight gains are shown in table 7.

/Table 7

46/ This estimate would include costs for land, land development, drainage, roads, buildings, processing plant, agricultural machinery, services and development feeds. B.H. Webb, *op. cit.*, table 10 and financial appendices.

47/ One study reports on the use of processed palm oil sludge (CENSOR process which mixes sludge with feed materials in a hot air rotary dryer) for poultry feed. The average cost per kilo weight gain was between M$ 1.38 and 1.45 (US$ 0.63 and 0.66) on the CENSOR diet while the weight gain costs for commercial feed diet was M$ 1.60 (US$ 0.73). Mortality and total weight gain for poultry on either diet was reported to be similar. (See B.H. Webb, and others, "Palm oil mill waste recovery as a by-product industry. Part I - mechanical aspects", *The Planter* (1975), 51 (588), pp. 86-101 and B.H. Webb, private papers).

48/ See R. Dalzell, "A case study on utilization of effluents and by-products of palm oil production by cattle and buffaloes on an oil palm estate", paper presented at the Symposium on Feedingstuff for Livestock, 17-19 October 1977, National University of Malaysia, Kuala Lumpur, Malaysia.

Table 7 Palm oil by-product feed formula, its effect on live weight gain, and costs thereof

Ingredients as percentage dry matter a/			Average daily gain (kg) c/		Average daily intake (kg) c/		Cost/kg live weight gain (M cents) d/	
Waste water b/	Press fibre	Salt	B e/	C e/	B	C	B	C
85.0	14.0	1.0	0.4	0.2	10.74	10.74	0.13	0.26

Source: R. Dalzell, "A case study on utilization of effluents and by-products of palm oil production by cattle and buffaloes on an oil palm estate", *op. cit.* tables 7 and 11.

a/ Vitamins A and D added (1 gram).

b/ Using waste water of 75 per cent moisture content.

c/ Plus grazing 3 hours daily.

d/ Cost of diet was M$ 0.05 and the daily cost was M$ 0.54 cents (as of 10 October 1975) with no cost for waste water or press fibre.

e/ B is buffalo and C is cattle.

/54

54. Table 7 indicates that a 99 per cent palm oil effluent and by-product feed formula produces an average of 0.4 kg daily weight gain in buffaloes at a cost of 0.13 Malaysian cents (US$ 0.6). Alternative formulae giving similar weight gains (0.45 kg), composed of 69.5 per cent palm oil residues, cost M$ 7.41 (US$ 3.37).[49/] No ill effects were found for the buffaloes or cattle, although a few general principles were advocated to avoid problems: "It was apparent that the use of press fibre at over 14 per cent of the dry matter composition of the ration, when fed to animals in stalls, could lead to digestive upsets. When press fibre was used in conjunction with grazing, (and with it, exercise of the animal) higher levels of up to 35 per cent press fibre have caused no problems. When the use of palm oil by-products constitutes a major portion of the animal's diet, fat (oil) ingested by the animal reaches levels much higher than in conventional rations. This high fat content probably limits the appetite level of the animal. This higher level of fat can cause severe digestive upsets until the animal has adapted to the ration. Where animals are to be confined, the introductory period for adaptation to the feed should extend up to 6 weeks."[50/]

55. The commercial potential of developing an oil palm effluent and by-product formula for cattle does not seem unreasonable. It is assumed that a feedlot adjacent to a 30 tonne per hour oil mill and obtaining palm oil residues free could obtain an annual accounting income, in excess of costs, of M$ 360,260 (US$ 163,754). The herd size should be 2,260 cattle and the formula would be the one used in table 8.[51/] The constraints in such a commercial enterprise are (i) producing a palm oil effluent which has a moisture content of 75 per cent or less, (ii) supplies of suitable animals and (iii) markets.[52/]

/56.

49/ Ibid., tables 7 and 11. The exchange rate is M$ 2.2 per one U.S. dollar.

50/ Ibid., pp. 17 and 18.

51/ Ibid., part V, "commercial potential."

52/ Ibid., p. 18.

56. Two observations can be made concerning the use of residues as feedstuffs. In all examples in this section, a clear problem has been in the marketing of the feedstuff product. In the Asian and the Pacific region, there is no doubt that the demand for cattle, swine and poultry products is increasing and consequently that for feedstuff is increasing. These increases are related to two tactors: population increase and increase in per capita incomes. The combined increase in population and effective demand, however, is thought to be more than the increase in supply of livestock or poultry products.[53/] In effect, an increased rate of the supply of livestock or poultry products is called for. However, there are two constraints to increases in cattle, swine or poultry supply (i) feedstuffs and (ii) the current composition of herds or poultry production, but as noted in this section, feedstuff is available from relatively cheap non-traditional materials. A more important constraint on livestock and poultry development is due to the fact that in most countries of Asia and the Pacific, livestock and poultry are a small farmer's business. Little centralization of herds of cattle in large feedlots has occurred. Poultry and swine management in south-east Asia is currently going through a period of centralization but no elsewhere in the region. The lack of centralization in livestock and poultry constrains the use of traditional feedstuff, in general, and the development of non-traditional feedstuff in particular. It is then not the aggregate demand which is important for non-traditional feed stock product, but the fact that supply is limited owing to the relatively small structure of the existing herds.

57. From the production side, in all examples in this section, the ex-factory cost of the non-traditional feedstuff is very low. The reason for this being so is due to the assumption that residues are free of cost; more importantly the assumption is that transport cost of the residues is negligible. These two assumptions imply that the residue producing factory and the residue-utilizing plant are industrially integrated. In many of the examples, a prime assumption is that the

/industrially

53/ T. Haseyma, "Demand for livestock products in Asian countries", Livestock Products in Asian Context of Agricultural Diversification, Asian Productivity Organization, Tokyo, 1976, pp. 31-33 and table 5.

industrially integrated factory also has attached a livestock or poultry rearing enterprise. This attachment also offsets transport cost and, in an accounting sense and perhaps in an economic sense, lowers the cost of livestock or poultry production.

58. It should be mentioned that the examples cited above are very limited, and should not be taken as a final judgement on residue utilization as feedstuffs. They do, however, point out that serious consideration must be given to marketing of the feedstuff product in the Asian and the Pacific area and in the system of production in order to assure economic viability of the enterprise.

D. Residues as fertilizers

59. The tradition in the Asia and the Pacific region is to use organic residues as fertilizers. Rice straw, maize stalk and cassava residue are ploughed back into the soil as a normal practice. However, in many countries of Asia and the Pacific vegetative matter has a competing use as a fodder which reduces its use as a fertilizer. There are also several constraints on the use of vegetative matter as a fertilizer apart from its competitive uses. One FAO/ESCAP report identified some of these constraints.[54/]

"It appears that there are four basic problems to the use of rural wastes as fertilizers. The first is the current unavailability of the material due to its use in a substitutable form or the present lack of centralized stable facilities making collection inconvenient. Second, there is a clear lack of knowledge about the proper and potential use of organic matter among farmers. Third is the great amount of labour reflected in high labour cost which must be utilized in order to collect, apply or convert the organic material into a more efficient form. Finally there is also a high cost involved in using land in an alternative form (green manure and legume crop production) other than for commercial crops."

/60.

54/ "Mission report: Organic matter from a socio-Economic perspective", FAO/ESCAP Workshop on Organic Materials as Fertilizers in Asia, 26 Oct.-5 Nov. 1976, pp. 11-11

60. Nonetheless, it has been pointed out that using vegetative matter (organic matter in general) as a fertilizer has positive effects on soil and crop productivity. Further, it has been suggested that the most economic use of vegetative/organic matter would be in combination with chemical fertilizers. It is doubtful, however, that an organic matter and chemical fertilizer combination would be readily accepted by Asian farmers as it shows little productivity gains over the chemical fertilizer substitute, especially in the short tun.[55/]

61. The 1979 ESCAP/UNEP mission team found that there had been little use of agro-industrial wastes as fertilizers, although sporadic use was evidenced. In the Philippines, for instance, sugarcane and paper mill effluents were used to offset costs of fertilizing coconut palms.[56/] Rubber and palm oil factory effluents were also reported to have been used in Malaysia to offset costs of chemical fertilizers for rubber and oil palm crops respectively.[57/] Very little economic data, however, exist concerning the cost-effectiveness of using agricultural and agro-industrial effluents as fertilizers. The reports which exist are concerned with the land-disposal of rubber factory effluents and their effect on productivity of rubber and oil palm relative to a control.

62. One such report on rubber factory effluent use as a fertilizer indicated that :

"Both rubber and oil palm responded positively to the nutrients, particularly N and K, and moisture in the effluent. Good over-all

/growth

55/ "Constraints on organic matter usage in rural Asia, paper presented at the FAO/ESCAP Workshop on Organic Materials as Fertilizers in Asia, 26 Oct.-5 Nov. 1976, section IV: Summary and Recommendations, and appendix I.

56/ ESCAP/UNEP mission notes on Canlubang Sugar Estate, Philippines.

57/ ESCAP/UNEP mission notes on Rubber Research Institute, Malaysia and Gatheries Estates, Chermara Research Station, Mvlaysia.

growth and yield performance was observed. At 3.81 cm rain equivalent per month (r.e.m.) and on a normal single-cut system, the rubber yielded 18 per cent more than the control (manuring according to routine estate practice) and 15 per cent with Ethaphen stimulation. Marked improvement
practice) and 15 per cent with Ethaphen stimulation. Marked improvement
in yield was also observed on a double-cut system comparing stimulation with Ethaphen and Stimulex giving respective yield increases of 18 and 11 per cent over control. Yield increase of about 19 per cent fresh fruit bunch over control was obtained in the oil palm field receiving effluent."58/

63. The savings obtained using the rubber effluent on oil palm (at 1.91 cm r.e.m.) in terms of equivalent nutrients contained in the effluent was calculated at M$ 3,438 (US$ 1,563) for oil palm. For rubber, it was calculated at M$ 3,039 (US$ 1,381) (at 1.27 cm r.e.m.) and at M$ 9,118 (US$ 4,144) (at 3.81 cm r.e.m.). It should be noted that in order to make a proper economic analysis these should be matched against the cost of an irrigation system for the effluent, the control cost of effluent treatment and discharge, and the opportunity cost of the effluents' alternative uses, if any. The report suggests that rubber effluent has a potential use as a fertilizer alth-ugh it should not be forgotten that the results come from a single experiment which did not take into consideration surface and ground-water contamination. However, it should not be overlooked that land-disposal fo agro-industrial effluents could be an alternative to treatment and stream-disposal, and might be the preferable method of disposal if economic considerations, relative to environment pollution were positive and if alternative uses of the effluents were not profitable.

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58/ Mohd. Tayeb Dolmat, Mohd. Zin Karim, Zaid Isa and K.R. Pillai, "Land disposal of rubber factory effluent: Its effects on soil performance of rubber and oil palm", mimeographed paper (Rubber Research Institute of Malaysia, and Chemara Research Station), no date, page 1.

E. Residues as chemical extracts

64. The 1979 ESCAP/UNEP mission found little, if any, commercial production of residues as chemical extracts. The current lack of interest in residues as resources for chemicals might be due to the lack of technical knowledge about conversion processes and the high capital cost of a processing factory, which would make the chemicals derived from residues much more costly than currently available ones.

65. The only chemical which has been produced from residues is activated charcoal, which is manufactured from charcoal. In the Philippines, the bulk of activated carbon exports went to Japan in 1976 and a volume of about 2,500 metric tonnes was exported, valued at about US$ 280 per tonne (f.o.b., Manila).59/ Prices for activated carbon, however, have fallen recently in the Philippines forcing closure of most of the manufacturing plants.

66. As of 1978, there was one activated carbon plant using coconut shells as the raw material in Malaysia.60/ Very little, however, is known about its operations, past or present.

III CONCLUSIONS AND OBSERVATIONS

67. Agricultural and agro-industrial residue utilization has been considered in this paper from the view point of economics. Only those residues which have associated with them an economic analysis have been featured; that is, only those residues which are currently being used on a commercial basis, or which have been subjected to pilot or feasibility studies, have been featured.

/68.

59/ The Philippine Coconut Industry, op. cit., p. 24

60/ Mohd. Nordin, Mohd. Som and Mohd. Hashim Hassan, Coconut Processing Industries in Peninsular Malaysia, Agricultural Product Utilization Division, MARDI, November 1978, Serdang (Selangor), Malaysia.

68. Table 8 reviews the availability of economic studies for the residues which have been investigated in this paper in terms of their potential end-uses.

/Table 8

Table 8 Residues investigated in the paper, their end uses and availability of economic report(s)

End-use	Residue	Product	Economic report (s) available (Yes/No)
Renewable energy source	Molasses	Ethanol	Yes
	Rice husk	Fuel	
		(a) Brick-making	No
		(b) Rice-mill operation	No
		(c) Electricity generation	No
	Bagasse	Fuel for sugar mills	No
	Coconut shell	Charcoal	No
	Coconut husk	Charcoal	No
	Any ligno-cellulosic material (rice husk, bagasse, rice straw, etc.)	Char, oil, gas (pyrolytic conversion)	Yes
Building materials	Bagasse	Paper manufacture	No
	Rice husk ash	Rice husk ash mixed bricks	Yes
	Rice straw	Compressed boards	Yes
	Rice husk, bagasse, rice straw, etc.	Particle boards (resin-binding)	Yes
	Any ligno-cellulosic material	Particle board (thermodyn process)	Yes
	Coconut stem	Parquet flooring, poles and posts, furniture, particle board, laminated beams, pulped paper	No

/Feedstuffs

End-use	Residue	Product	Economic report (s) available (Yes/No)
Feedstuffs	Rice bran and straw, maize stalks, copra cake, sugarcane press mud and tops, cassava residues	Livestock and poultry feedstuffs	No
	Rice bran oil	Human food, industrial use	No
	Molasses-nitrogen feedstuffs	Livestock feedstuffs	Yes
	Bagasse-molasses feedstuffs	Livestock feedstuffs	Yes
	Cassava foliage	Protein feedstuffs for livestock, and poultry	Yes
	Palm oil by-products	Livestock and poultry feedstuffs	Yes
Fertilizers	Rice straw, maize stalk, cassava residues, vegetative organic matter	Organic manure	No 61/
	Sugarcane effluents, palm oil factory effluents	Organic manure	No
	Rubber effluents	Organic manure for rubber and oil palm	
Chemicals	Coconut husk, coconut shell	Activated charcoal	No

61/ A paper has been previously written on the general economic use of organic matter as fertilizers, see "Constraints on organic matter usage in rural Asia", *op. cit.*

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69. Of the sampled residues and their potential end-uses, table 8 suggests that little has been done concerning the economics of residue utilization. The current approach is to study residue utilization from product potentially without considering in tandem the economic potentiality of its use. This is not to deny the potential utilization of agricultural and agro-industrial residues. Reports have suggested current medium-term and future uses of residue-related products. For instance, a recent report suggested that a good possibility exists for using agricultural and agro-industrial residues in the medium and future term for such diverse products as methane and other energy sources, yeast and algae, paper (from fibrous wastes such as oil palm fibre), and furfural. Residues could also be used in the form of cellulosic materials for producing enzymes and antibiotics, and, through solvent recovery process, for obtaining oil.[62/] The problem remains that the economics of these potential residue related products is not yet developed.

70. The present review has also attempted to clarify some of the basic problems which would need to be tackled if agricultural and agro-industrial residues were to be used. In general, residue utilization should be considered one aspect of environment protection and, as such, can be compared to the treatment of polluting effluents. In this regard, it is not necessary for residue processing to be profitable from an accounting point of view as long as it has positive value from a point of view which takes into consideration economic (and opportunity) costs and social benefits. For a commercial enterprise, however, profit counts. It is thus important that any national environmental protection programme should recognize this fact and introduce incentives through regulation or fiscal policy to stimulate enterprises which embark on production processes using residues as resources. Proper consideration should also be given to the short and medium-term displacement of capital for other developmental tasks in relation to starting such a programme. In this regard and because most environmental protection policies in Asia and the Pacific are in their infancy, many policy options remain open. How

/much

62/ See B.H. Webb, op. cit.

much, for instances, should a Government emphasize treatment and stream-disposal of pollutants? To what extent should a Government set standards for pollution control rather than impose taxes on the polluting enterprise based on its polluting output and the nature of its surrounding ecosystem?[63/]

71. The basic question remains how far a developing country can divert resources from development needs to protect its environment at the present time. That is to say, how much of the cost of current pollution is a Government willing to pass on to later generations for payment? These are not simple questions, nor can simple answers be given. What is known to date and, in effect, what is described in the examples of residue utilization in this paper can be taken as an indication of the features involved in developing a national environment protection programme, one component of which is based upon residue utilization.

72. These features are :

(a) Some residues can be currently used and give economic returns to an enterprise. It is expected that changing economic conditions will aid in the development of such economic utilization patterns overtime owing to developing conditions of resource scarcity and the development of appropriate technologies;

(b) Some residues cannot be currently used. However, regulations and fiscal policies can be manipulated to promote residue utilization now instead of in the future. The potential residues for use should be determined (from the technical and economic view points) before implementing such a policy in order to obtain from it optimum social benefit;

(c) Trade-offs could be made between treatment-disposal and processing-use. But it must be realized that processing may produce other and perhaps more environmentally destructive residues in its second generation production process;

/(d)

63/ It is argued that a tax system is more egalitarian than a standard system as the latter tends to produce adverse economic affects on small-scale enterprises. See D.W. Pearce, *op. cit.*, Chsp. 4.

(d) Markets for the residue products must be developed over time. This development may include informing consumers of the potential products and their value, and changing the socio-economic structure of the consuming entity (for instance, developing large-scale feedlots for cattle rather than supporting small herds);

(e) The most economic production of residue products tend to be connected to an integrated industrial approach. Such an approach reduces costs of production by decreasing transportation costs, at the very least. This leads to a policy of support for medium to large-scale, rural-based industries;

(f) Prior to embarkation on an environment protection programme, a complete economic analysis is called for in order to aid in the development of rationally-based policy decisions;

73. In the final analysis, it is not that all agricultural and agro-industrial residues can be used. It is that agricultural and agro-industrial residues may have an economic base for utilization given rational policy, socio-economic considerations, appropriate technology and time.

INSTITUTIONAL ASPECTS OF AGRICULTURAL
AND
AGRO-INDUSTRIAL RESIDUE UTILIZATION

INSTITUTIONAL ASPECTS OF AGRICULTURAL AND AGRO-INDUSTRIAL RESIDUE UTILIZATION

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I INTRODUCTION

The utilization of agricultural and agro-industrial residues could serve dual purposes. On the one hand, rational management on the implementation of policies, encouraging and promoting more efficient processes will generate less residues and hence result in increased production from the agricultural and agro-industrial sectors. This can be translated directly into increased food output. On the other hand, rational management resulting in greater use and recycling of agricultural and agro-industrial residues will also mean less materials being discharged into the air, water and land systems of the biosphere. With less pollutants entering the biosphere, consequently the ecological basis required to sustain production will be enhanced and increased.1/

Recognizing the importance of residue utilization, UNEP and FAO had jointly organized a global seminar on "Residue Utilization - Management of Agricultural and Agro-Industrial Wastes" in Rome in January 1977 with the objectives to :

a. Provide an over-all survey of the main problems of wastes and residues associated with agriculture, fisheries, forestry and agro-industries;

b. Review the experience and technology available to solve these problems;

/c.

1/ Residue Utilization - Management of Agricultural and Agro-Industrial Residues - an Overview, UNEP/FAO, UNEP Industry Programme, Paris, May 1977, pp. 5-6.

c. Discuss economic, social and political situations that are compatible with conducive to environmentally sound residue utilization;

d. Identify existing gaps and possible action programmes to fill such gaps; and

e. Assess the relative importance and priorities of such action programmes and outline a framework for international co-operation.[2/]

During the seminar, it could be observed that the situation in developing countries in Asia and the Pacific warrants a different approach. Due to their dominant agricultural base, the immense potential in utilizing agriculture and the associated agro-industry residues could be recognized. At the same time, agro-industry has become one of the main sources of pollution in developing countries. Although effluents released from agro-industry, in fact, are not toxic and could be converted to useful by-products, the amount of effluent loads and the associated oxygen requirement is of such a magnitude that it often creates a nuisance and pollutes the environment.

Realizing the diverse characteristics of different regions of the world, it was thus recommended that further regional meetings should be organized to concentrate on specific issues relevant to regional situation and needs. At the same time, FAO as a follow-up of the Rome Seminar, had conducted a global survey on the status of agricultural and agro-industrial residue utilization. The accumulated information could serve as one of the bases for regional meetings.

In Asia and the Pacific, the UNEP Regional Office, fully aware of the potential of renewable and reusable resources in terms of agricultural and agro-industrial residues, had organized a consultative meeting in March 1979 with participants from Japan, Australia, New Zealand, Sri Lanka, Philippines, Malaysia, Thailand and Indonesia with the objectives to :

a. Explore the merits of establishing a network of applied research institutes on technology for renewable resources. It is expected

/that

2/ *Ibid*, p. 6.

that such a network will be formed from existing institutes of scientific and technological research and linked with on-going activities in developed countries of the region.

b. Promote concrete national research by institutes referred to in a. on renewable resources and residue utilization of selected commodities such as palm oil, coconut, forest products, tapioca, sugarcane;

c. Strengthen the exchange of information among research institutes participating in this exercise which may eventually lead to regional programmes on renewable resources and residue utilization.

The meeting fully endorsed the idea of establishing a regional network of research institutes in technology for renewable and reusable resources. The meeting also confirmed the abundance of residues from agriculture and agro-industry in the region. Governments are aware of the hidden potential of these resources which may serve multifarious functions such as fertilizer, animal feed, chemicals, construction materials and sources of energy.

For Asia and the Pacific region, UNEP together with the Regional Commission (ESCAP) and FAO had undertaken to pursue the promotion of residue utilization by organizing a regional workshop in Pattaya in December 1979. This meeting will serve as the forum for discussing the various aspects vital to the successful utilization of residues in developing countries of the region. The objective is also to increase the awareness of environmental problems related to agricultural and agro-industrial residues.

In the preparation for the meeting, a mission to visit five selected countries in the region, viz. Thailand, Philippines, Malaysia, the Republic of Korea and Pakistan was mounted in August-September 1979. It was decided that the scope of the mission should be specific and covered the major crops of the region, viz. rice, maize, tapioca, sugarcane, oil palm, coconut and rubber.

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In promoting residue utilization, it is realized that institutional structure plays an eminent role in enhancing the pace of development. The objective of this paper is to assess the existing institutional structure on residue utilization in developing countries of the region, particularly in the five countries visited.

II INSTITUTIONAL PATTERNS ON RESIDUE UTILIZATION

The intention of this chapter is not to evaluate the existing governmental structures on residue utilization. Governmental mechanism is the result of the dynamic evolution based upon the political, social and economic development which is unique to each country. It thus may not be constructive to expose any weakness in a governmental structure without tracing the historical bureaucratic development which the government has to comply with. To avoid this pitfall, the stress of this chapter is rather on presenting a perspective picture depicting the situation in the region, particularly the experience in the five countries visited during the mission.

Institutionally, the promotion of residue utilization cuts across governmental functional lines and is being undertaken under the auspices of various ministries such as ministry of science and technology, ministry of agriculture and ministry of industry. This depends very much on the existing organizational structure of a country.

For agricultural and agro-industrial products, there are numerous examples of the utilization of agricultural residues such as rice straw in making straw board, sugarcane tops for animal feed, or trunks from rubber and coconut trees as construction materials. In fact, residues or by-products can be promoted into vital input for further production which may yield higher economic return such as the production of industrial and fuel alcohol from molasses.

/Generally

Generally speaking, the management of agro-industrial residues should be carried out in three consecutive steps. Firstly, the assurance of the efficiency of the process itself, so as to minimize the amount of residues generated. Secondly, the promotion of the utilization of residues to the extent possible taking into consideration the prevailing economic viability and social acceptability. Finally, the control of unavoidable waste to minimize the impact to the environmental quality.

The awareness and interest of governments in promoting residue utilization varies from country to country depending on its agricultural and industrial activities, and the unique situation of a particular country. In Malaysia, the Government had organized a national seminar on the Scope for Materials Recycling by the Standards and Industrial Research Institute of Malaysia (SIRIM) with participants from governmental agencies, universities and industry in October 1978. The result has sharpened the focus of the government in augmenting its research effort on residue utilization.

In the Philippines, the country will embark on a National Coconut Replanting Programme from 1980 to 2020 for its 2.5 million hectares of land under coconut cultivation plus an additional 0.4 million hectares. This means the replantation of 350 million coconut trees. At present 40 per cent of these trees are over 60 years old. Hence there is an enormous potential for the utilization of coconut trunks and other residues.

Besides, the Ministry of Human Settlements of the Philippines is looking into the nutritional value of copra as a protein supplement for rural people. Since coconut is the dominant commodity in the Philippines, with one-third of its population depending on this crop for their livelihood, the National Cottage Industry Development Authority is trying to promote fibrecraft from coconut trees through its cottage industry development programme. This will serve in supplementing income of the rural poor and will contribute towards rural development.

/Recently

Recently in Sri Lanka, a natural cyclone had uprooted vast amount of its coconut stock. As a result, the government was confronted with the sudden availability of fallen trunks which should be utilized prior to their decay if appropriate technology was available. In another country, due to internal security, research on the utilization of agricultural residues for use in emergency situation has been carried out as a precautionary measure.

MAJOR GOVERNMENTAL AGENCIES ON RESIDUE UTILIZATION

Thailand

Thailand is a traditional major food exporting country. Out of the seven crops under consideration, Thailand has substantial surplus and exports large quantity of five of them. Projected production figures for 1979 are :-*/

Rice	16.9 million tons
Maize	3.3 " "
Sugarcane	19.0 " "
Tapioca	13.0 " "
Rubber	495,000 tons

With the abundant amount of agricultural products which are more than enough to feed its population of 45 million, there is bound to be an associated large amount of residues available for utilization. Ironically, however, due perhaps to the magnitude of agricultural yields, the traditional use of the agricultural residues such as stalks, straws, leaves is mainly for animal feed in the fields or fertilizer in the form of burned ashes.

At the same time, through its market economy system, the private sector has taken advantage of the availability of agricultural supply and

/has

*/ Source: Ministry of Agriculture and Co-operatives, Bangkok, September 1979.

has invested substantially in agro-industry such as rice mills, sugar mills, tapioca plants and in rubber production. Due partially to lack of technical understanding, residues from sugar mills and tapioca starch plants have at times caused pollution in the receiving water bodies.

Notwithstanding, there are quite a few good examples in the country on residue utilization at the commercial level. As an example, a local firm has been manufacturing and marketing building boards from rice straw through imported technology. By the process of compressing straw under heat, fire resistant boards of great strength can be produced, suitable for building construction. This practice is particularly beneficial to Thailand considering the availability of straw in the country.

Thailand Institute of Scientific and Technological Research (TISTR) under the Ministry of Science, Technology and Energy, as its name implies, is responsible for conducting applied research for industrial applications. It fully realizes the potential of agro-industry in the country and has stressed the utilization of agricultural and agro-industrial residues. As an example of its success, TISTR has been instrumental in promoting the utilization of rice straw in making paper in conjunction with other raw materials.

TISTR has maintained close contact with industry, Lately it has promoted the development of appropriate technology for application at the rural level, such as

- coconut coir dust for making nursery blocks
- tapioca leaves as animal feed
- rice husk as mixing material with lime sludge in making cement
- corn cob for making light weight bricks.

Other institutes involved in residue utilization include the National Research Council (NRC) which is mainly responsible for promoting research throughout the country. At the Ministry of Agriculture and Cooperatives, the main emphasis is on the promotion of crop production and the increase in crop yield. However, through its existing network, residue

/utilization

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utilization can be easily incorporated into its work programme. This also applies to other ministries, particularly the Ministry of Industry, under which exists the Sugar Institute which is in charge of promoting the sugar industry.

On the environmental front, the Ministry of Industry, through its Department of Industrial Works (DIW), is responsible for regulating industrial effluents. Agro-industries particularly sugar mills and starch tapioca mills have been branded as major polluters to rivers and coastal beaches. A few years ago, effluents from sugar mills had caused annual pollution in the Mae Klong river, which is a major river west of Bangkok. To control this pollution, DIW has set up a task force to regulate and control the quality of effluents released from sugar mills. Concerted effort was solicited from the mills in terms of investment on pollution control equipments such as aerators and the construction of aerated lagoons. Due also to the high water flow during the past few summer seasons, the government has succeeded in controlling the pollution of this river.

The National Environment Board (NEB) which was set up in 1975 is responsible for the setting of ambient quality standards. It advises the government on policy matters dealing with environmental quality. NEB is working closely with DIW on environmental quality management including the control of effluents from agro-industries.

Philippines

In this country there is high awareness of the potential of residue utilization of agricultural and agro-industrial products. Since Philippines has to import its energy mainly in the form of petroleum, it has given priority to the production of fuel alcohol from sugar to serve as another source of energy.

Organization-wise, there are quite a number of governmental agencies concerned with various aspects of residue utilization. Instead of having one ministry in charge of all agricultural products, the government has set up specialized agencies for each major commodity such as coconut, sugar and grains.

/The

The Department of Agriculture plays the nodal role in policy matters concerned with agriculture. It has been instrumental in formulating the food policy and plan of the country.

The National Grains Authority (NGA) is responsible for rice, corn and tapioca. Although NGA reports directly to the Office of the President, it co-operates closely with the Department of Agriculture. It has established a national network covering the purchasing, warehousing and selling of these three commodities. NGA controls about 10 to 15 per cent of rice production in the country.

With the increasing energy bill, NGA is promoting the burning of rice husk to produce energy in rice mills. NGA had established a National Post-Harvest Institute for Research and Extension. Other researches include experiments on pyrolytic convertion using husk, straw and saw dust.

Philippines Coconut Authority (PCA)

PCA has been instrumental in maintaining the Philippines position as the foremost coconut producer of the world. It has a comprehensive and elaborate set up which has drawn upon full participation of the private sector such as the Philippines Coconut Producer Federation, Coconut Association of the Philippines, Coconut Plantation Bank. Concurrently, it has an extensive research programme covering agricultural, industrial and marketing activities. It is in the final stage prior to the embarkation on a National Coconut Replanting Programme which will commence in January 1980 for a forty-year period up to the year 2020.

With one-third of the entire population in the country dependent on coconut, there is an enormous potential for residue utilization from this tree. On-going activities include the use of coconut coir as stuffing material for upholsteries, the promotion of copra as a protein substitute for rural nutrition programmes and the development of fibrecraft cottage industry from coconut residue.

A Coconut Consumers Stabilization Fund was established since 1973 with a levy of 60 Peso for every 100 kg. of copra. The generated fund is used for various purposes such as replantation and assistance to coconut farmers.

/Philippines

Philippines Sugar Commission (Philsucom)

To respond to governmental policy in promoting full scale development of fuel alcohol from sugarcane, Philsucom has set up a task force to study this issue in detail. The present plan calls for the construction of 10 plants worth 2.8 billion Peso to produce fuel alcohol.

There is an ingenious sharing system between the planters and millers by which 25 to 40 per cent of the products from the mills will be paid to the millers while the planters receive 60 to 75 per cent. With this arrangement, direct purchase from planters can be avoided, and the profit from sugar industry is more equitably shared.

Similar to the PCA, a levy of 2 per cent of the producers gross income is in effect which provides the necessary fund for research and development.

Philippines Council for Agriculture and Resources Research (PCARR)

Affiliated with the National Science Development Board, PCARR with its comjrehensive network of research is the foremost agriculture and resources research centre in the country. It supervises extensive research programmes on forestry, soil and water resources, mines, fisheries, livestock, crops, and socio-economic research. Its major thrust is to carry out action-oriented research. In calendar year 1978, PCARR monitored more than 78 million Peso worth of research projects.

National Pollution Control Commission (NPCC)

As its name implies, NPCC is the enforcement arem of the government in regulating environmental quality standards. It has established a monitoring network for air and water quality. NPCC is responsible for setting up environmental quality standards. Recently, it has embarked on a vigorous air pollution control programme particularly aiming at public buses in the Metro-Manila area. After more than one year in operation, NPCC claims that the level of carbon monoxide has been markedly decreased.

/National

National Environmental Protection Council (NEPC)

Established only since 1977, NEPC serves in promoting environmental awareness among the public, determines priority areas and promotes environmental research and evaluates development projects to minimize the adverse effects to the environment. Through Presidential Decree 1152, a tax incentive system is currently operational and applicable to investment on pollution control equipments and research on pollution control technologies.

Republic of Korea

The Republic of Korea has experienced a high growth rate during the past fifteen years with an average annual growth of 10 per cent. The achievement in the economic field is due partly to the strong base in science and technology. The emphasis of the country is on industrial development in which agro-industry plays a secondary role. Korea is blessed with the understanding by the highest level of the importance of the role of science and technology to development.

Office of Rural Development (ORD)

ORD is responsible for the renowed Saemuel Undoing rural development programme which has been credited with the success in raising the standards of living of the rural areas to par with those in the urban centres. Devoted entirely to rural development, ORD has sponsored research on the use of agricultural residues to maximum advantage in emergency situations.

Korean Institute of Science and Technology (KIST)

This well-known institute has full in-house capability consisting of more than 200 Ph.Ds. Its sources of fund come from both the private sector and from the government, the latter to insure the continuation of long-term research. It has established liaison offices in Washington and Tokyo.

/The

The policy is to acquire the best technology suitable for local conditions either through the adaptation of imported technology or through indigenous research in the country. Although it is concerned mainly with industrial development, it also supports studies on residue utilization such as the use of rice husk in making particle boards.

KIST has established an Environmental Engineering Research Department under which various contract research has been conducted for private industries such as the environmental assessment of fertilizer complexes.

Bureau of Environmental Control (BEC), Ministry of Health and Social Affairs

BEC is heavily involved in establishing a new national environmental agency with definite functions in planning, co-ordination, air and water quality management, monitoring, and research and development. It is expected that this new office will become operational from the beginning of 1980.

BEC is also preparing a ten-year long-term comprehensive environmental preservation plan in co-operation with other governmental agencies. Its main concern seems to be on the management of industrial effluents and emissions.

Malaysia

Malaysia, similar to the Republic of Korea, has attained a relatively high degree of economic development. It has a successful agricultural development programme particularly on oil palm and rubber. Malaysia enjoys a high degree of interagency collaboration within its bureaucracy which serves as a positive factor contributing to national development.

Malaysian Agricultural and Research Development Institute (MARDI)

MARDI is a statutory state enterprise. It has ample research funds of about M$ 40 million annually. MARDI's emphasis is to utilize residue as animal feed. It has an extensive field service of 25 stations all over the country.

/Ministry

Ministry of Science and Technology

Under this ministry, the Division of Environment (DOE) has set up a vigorous programme on environmental quality management. A stage-wise reduction of BOD content in the effluents from palm oil mills and rubber has been set and is rigorously enforced. As a result, it has been observed that the water quality has improved in some major rivers.

There is a high degree of inter-departmental collaboration. A striking example is the division of responsibility and labour regarding environmental quality management. DOE emphasizes enforcement and planning, whereas the Standards and Industrial Research Institute of Malaysia (SIRIM) is responsible for technical research including training, and the laboratory works is analysed by the Chemistry Department. SIRIM also serves as the nodal agency in food wastes research in collaboration with MARDI and universities.

Rubber Research Institute of Malaysia (RRIM)

Being the world's leader in rubber research with about 40 per cent of the world's natural rubber production, RRIM has been successful in improving rubber yields. Similar to the Philippines practice in coconut, RRIM places a levy of 1 Malaysian cent for every pound of dry rubber produced. This generated revenue is sufficient to promote RRIM activities including the replantation programme.

Since its inception in 1925, RRIM has been technically conscious. It publishes a regular technical journal and roganizes annual meetings and seminars which serve as the forum for propagating modern technology from its research. RRIM has set up a Technology Centre providing services and facilities on all aspects of rubber industry, viz. latex technology, technological research, rubber in engineering, test models and specification, technical advisory services, and product development and processing. On residue utilization, it is conducting research on the use of rubber effluents directly as fertilizer and for algae production for fish feed.

/Pakistan

Pakistan Agricultural Research Council (PARC)

PARC co-ordinates all agricultural research both at the federal and at the state levels. Recently PARC has been involved in promoting the recycling of crop residues and other organic wastes for livestock feeding particularly from molasses.

PARC has now become an autonomous body with close relation with the Ministry of Food and Agriculture, agricultural research institutes and other agricultural universities.

Pakistan Council for Scientific and Industrial Research (PCSIR)

PCSIR is well endowed with qualified educated staff with more than 300 with advanced degrees in science and engineering. In residue utilization, there are various research programmes including the utilization of rice husk for making activated carbon, of which the pilot scale testing is expected to commence in 1980. There is also joint research with the Denver Research Institute in converting corn cob to animal feed.

Structure-wise, PCSIR has a decentralized research programme. There are research laboratories in major cities of Karachi, Lahore and Peshawar. PCSIR has been quite successful in the study of making cement from rice husk which is now at the pilot scale testing for commercial application.

Appropriate Technology Development Organization (ATDO)

This is an autonomous semi-governmental agency under the Ministry of Science and Technology. It is responsible for promoting appropriate technology for rural development. It co-operates with other research agencies such as PCSIR or PARC regarding research and development. Activities of ATDO include programmes on recycling of organic and agricultural wastes, and the utilization of rice husk in making cement in collaboration with PCSIR.

/ROLE OF

ROLE OF HIGHER LEARNING INSTITUTES

In developing countries, universities and other higher learning institutes play a relatively more significant role as centres of technical know-how. There is normally a cluster of qualified technical manpower associated with a university. Besides teaching, technical research is another requisite function of universities. In this regard one can refer to the study on food residues by the Institute of Food Research and Product Development, Kasetsart University, Bangkok;and the Ravi river pollution study by the Institute of Public Health Engineering and Research of the University of Engineering and Technology in Lahore, Pakistan.

Besides research, universities can also co-operate with other governmental agencies in organizing seminars, workshops and other training courses both for technical professionals and the public at large. It is interesting to note that Kasetsart University has set up an educational programme for the development of small farmers. The objective is to acquaint the farmers with modern technology. At the same time, it gives the opportunity for the students and faculty alike to mingle freely with the rural farmers. This has proved to be psychologically beneficial in the long run in attuning the attitude of the graduates to the situation and needs of the majority of the people in a country.

ROLE OF THE PRIVATE SECTOR

In a market economy, it is the private sector that commercially develops research products into market valuables. With the expansion of international trade, local affiliations tend to import technology from their headquarters. Local firms also have the tendency to adopt imported process technology through licensing.

The strength of the linkage between the government-supported research institutes and the private sector is vital to the development of indigenous capability in science and technology. The success of the Republic of Korea in industrial development clearly amplifies this attitude.

/It

It is the private sector who financially has to bear the economic viability of commercial products. Hence the private sector must fully appreciate the benefits of residue utilization prior to full development of its potential in a country.

The innovative and well-publicized Kamol Kij rice mill and farm complex in Pathumthani, Thailand is a distinct exvmple of the initiative by the private sector. This mill has a capacity of 450 tons a day. The rice produced is mainly parboiled for exporting. The main residue from the milling process, rice husk, is fed directly as fuel for steaming in the parboiling process. Crude oil is extracted from other the main residue, rice bran, while the defatted bran is fed to chickens, ducks and pigs in the affiliated farm where the concept of residue utilization has been put into full practice. Chicken coops were built on top of pig pens so that chicken droppings can be directly consumed as part of pig feed. Pig droppings, in turn, are fed to fish ponds to raise the local fish species of Tilapia Nicolatica, Clarius Batrachus and Pangasius Sutchi. To complete the cycle, there are experimental farms utilizing the sediments from fish ponds as fertilizer for crop production such as corn.

On environmental quality management, it is heartening to note the initiatives being undertaken by some private industries in managing their effluents. A kraft paper mill in Thailand, Siam Kraft, has installed an efficient water treatment system with operating and maintenance costs amounting to 0.5 per cent of its sales volume. It has set up an environmental section devoted entirely to environmental management. Under the pioneering effort of this section, experimental farming utilizing the effluents as irrigation water is undertaken in adjacent fields. The results show substantial increase in both cane yield, and rice yield compared to the average production in the area.

/III

III SELECTED CASE STUDIES FROM THE REGION

For such a study on institutional aspects, it is best to observe the existing success cases and to learn from their experience. The case studies presented in this chapter, although not necessarily dealing directly with residue utilization, represent the feasible set-ups which may be adapted to residue utilization promotion programmes.

COCONUT PROMOTION AND DEVELOPMENT IN THE PHILIPPINES

Agriculture by all means still serves as the dominant sector in most developing countries in Asia and the Pacific. Agricultural commodities remain major sources of national income and foreign exchange earnings. Agricultural commodity developmtnt thus plays a significant role in the economic developmtnt of a developing country.

Importance of the Coconut Industry in the Philippines Economy and Potential for Residue Utilization

In 1976 coconut occupied 22 per cent or 2.5 million hectares of total agricultural land. In this same year, the Philippines contributed 77 per cent of total world export of copra and 83 per cent of total world export in terms of coconut oil. The coconut industry provides livelihood to roughly one-third of the population in the country, or about 14 million. This is even more significant considering that twenty-five per cent of foreign exchange comes from the coconut industry.

In the processing of coconut for the production of copra, coconut water, which is between 26 and 29 per cent of the weight of the coconut, is wasted. The value of coconut water produced is approximately 136 litres per 1,000 nuts. Coconut water contains 5 per cent total solids including 2-3 per cent sucrose. If this water, which is easily isolated, can be concentrated a solution of 15 per cent to 20 per cent sugar can be produced, which could be used for the production of wine, vinegar, alcohol, yeast, syrup or directly as a beverage for human consumption.

/Another

Another residue is coconut fibre dust. This is currently wasted, but it could be made into building materials after appropriate processes are developed and demonstrated. The production of 22½ billion nuts available is estimated to generate 2½ mt of dust.

Coconut shell is another potential source of wealth in the form of activated carbon, while coconut stem represents a valuable timber resource which can be utilized as a building material.

Philippines Coconut Authority

Recognizing the importance of coconut to the development of the country, the Philippines Government has established an autonomous agency for coconut since 1954 in the form of the Philippines Coconut Administration which was later transformed into the Philippines Coconut Authority (PCA) in 1973.

The present major functions of PCA include agricultural research and development, industrial research and development and marketing research and development. It has established regional research extension centres for training governmental officials and industrial workers. At present, the Governing Board consists of seven members and is well represented by the private sector. Three members of the Board are representatives from the Philippines Coconut Producers Federation (COCOFED) while one member represents the United Coconut Associations of the Philippines and another member represents the United Coconut Plantation Bank. Such a representation has so far ensured the benefits of both the coconut growers and the industry. To properly serve the Board and fulfil its functions, PCA relies on the strength of its staff which consists of more than 1,400 technical persons.

/National

National Coconut Replanting Programme (NCRP)

This is the predominating programme of PCA which will commence in January 1980 up to the year 2020 covering 2.5 million hectares of land and 350 million trees. Forty per cent of the present stock of coconut trees in the country are over 60 years old. In 1978, the total exported value of coconut products amounted to $941 million. This figure is likely to surpass the one billion dollar mark in 1979. The total land area under coconut plantations, will be expanded by another 0.4 million hectares under NCRP. Although the income of the present growers is only 800-1,000 Peso per hectare per year, the Government expects to increase the yield through the replanting programme and raise the income of the coconut growers to more than five times the present level. Many of the farmers are small holders with 90 per cent occupying less than 5 hectares and only 0.3 per cent occupying more than 50 hectares.

The Government is fully aware of the potential of the utilization of coconut products. There is a programme jointly undertaken with the Ministry of Human Settlements to increase the protein intake of rural population through the high nutritional value of copra. At the same time, cottage industry is being promoted jointly with the National Cottage Industry Development Authority under the Ministry of Trade on the development of fibrecraft. PCA has promoted training programmes for trainers in cottage industry. It also provides loans, from 500 to 2,500 Peso for each participant.

Generation of Fund

An ingenious scheme of generating funds for PCA to cover its operational and development costs has been in operation since 1973. A levy of 60 Peso for every 100 kg. of copra is charged as contribution to the Coconut Consumers Stabilization Fund (CCSF). At the present rate of production, a total amount of 1,200 million Peso can be collected annually which is distributed as follows :

/ - 20 Peso

- 20 Peso per 100 kg. for the National Coconut Replantation Programme;
- 12 Peso per 100 kg. as subsidy to coconut-based consumer products such as cooking oil, soap, copra meal;
- 8 Peso per 100 kg. for the coconut industry investment fund for the acquisition and improvement of old mills;
- 15 Peso per 100 kg. for social benefits to farmers. This includes the United Coconut Planters Bank, the United Planters Life Insurance Corporation, Hybrid Seedings Distribution Programme, Fertilizer Assistance and Copra Trading Corporation.
- 2 Peso per 100 kg. for the operational fund of PCA;
- 2 Peso per 100 kg. for COCOFED;
- 1 Peso per 100 kg. for scholarships for education of farmers' youths.

Salient Characteristics of PCA Programmes

Being self-sufficient in funds, PCA has the necessary resources to carry out its programmes. Besides, with the representation in the governing board of both industry and farmers, this ensures a more equitably distribution of income generated from the coconut industry to small farmers.

Admittedly, the vast potential of coconut residues such as stem, coir dust, fibre, has yet to be fully exploited at the commercial level. With the existing organizational structure, however, the environmental dimension in terms of residue utilization can be easily incorporated into the PCA work programmes.

SCIENCE AND TECHNOLOGY DEVELOPMENT IN THE REPUBLIC OF KOREA

The success of the Republic of Korea in science and technology is well acknowledged. The latest figure in 1977 showed that 0.8 per cent of the GNP was invested on research and development with a government to industry ratio of 70 to 30.

The importance of science and technology to the economic development of a country has been fully recognized from the highest level in

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the Republic of Korea. As a result, there is a clear and distinct strategy on various stages of scientific and technological development, the outlines of which can be delineated as follows :

1960s: 1. Strengthen science and technology;
2. Build up a scientific and technological infrastructure;
3. Promote foreign technology imports.

1970s: 1. Expand strategically important skilled training;
2. Improve institutional mechanism for adapting imported technology;
3. Promote research applied to industrial needs.

1980s: 1. Expand facilities for advanced scientific and engineering manpower;
2. Develop export of technology and engineering know-how;
3. Promote long-term advanced research and strengthen development of systems research. 3/

The present fourth five-year economic development plan which covers the period from 1977 to 1981 will increase the total research and development investment of the country up to at least 1.5 per cent of GNP by the year 1981. At the policy level, the Ministry of Science and Technology is now moving into long range planning with the formulation of a twenty-year development plan for science and technology.

Major Legislations

Under the technological development promotion law, tax, credit and loan privileges for research development and investment are made available to interested industries. The series of important legislations related to science and technology are :

(a) The Science and Technology Promotion Law of 1967 provides a basic commitment of the Government to support science and technology, and policy leadership;

/(b)

3/ Science and Technology for Development in the Republic of Korea, a contribution to the 1979 United Nations Conference on Science and Technology for Development, Republic of Korea, 1979.

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(b) The Technology Development Promotion Law of 1972 supports private and public corporate enterprises in their scientific and technological development efforts through tax privileges and other incentives;

(c) The Engineering Services Promotion Law of 1973 provides for the strengthening of the capabilities of local engineering firms;

(d) The National Technical Qualification Law of 1973 promotes the status of engineers and craftmen;

(e) The Law for Assistance to Special Research Institutes of 1973 provides incentives in legal or financial terms for research institutes in specialized fields such as ship-building, electronics, communications, mechanical and material engineering and energy;

(f) The Laws for Korean Science and Engineering Foundation of 1976 provides a legal basis for the establishment of a foundation to support basic research in pure and applied sciences mainly academic institutes.[4/]

Major Science and Technology Institutes

(a) Korean Institute of Science and Technology (KIST)

KSIT is the foremost multidisciplinary research institute in Korea. It is a state enterprise with more than 200 Ph.Ds. It draws upon research contracts from the industrial sector which constitute about 60 per cent of its generated fund. The other sources of income are endowment funds and government projects. It has a total of 700 research scientists. It is expected to reach the 10 billion Won mark in research investment in 1979.

Since its inception, it has been successful in recruiting national experts and bringing back Korean expatriates working in developed countries. The success may be attributed to its ability to create a working environment suitable to the needs of Korean scientists and engineers. The honorarium provided is also competitive compared to the private sector.

/Planning

4/ Ibid.

Planning now from past experience, KIST's present policy is to draw upon the funds from both the government and the private sector. Private industries serve in funding short-term and ad hoc projects fit for specific needs of the respective industries, whereas the fund from the government is utilized in basic and long-term research vital to the success of scientific and technological development of the country.

(b) Korean Advance Institute of Science (KAIS)

To fulfil the long-term requirement in terms of scientific and technological manpower, KAIS was established in 1970 as an institute of higher learning in priority areas identified by the Government. It mainly offers graduate courses leading toward advanced degrees in science and engineering.

(c) Korean Scientific and Technological Information Centre (KORSTIC)

Flow of information is vital to the successful transfer of technology. KORSTIC was established in 1972 as the main science and technology information centre. It has a comprehensive scientific information compilation and dissemination system. KORSTIC serves as the prime liaison centre with international information sources. Domestically, it has established direct linkages with the private sector mainly in transferring technical information for industrial uses.

(d) Ministry of Science and Technology

This is the main governmental agency responsible for setting up policy on science and technology. The Republic of Korea intends to increase the share of the private sector in science and technology investment up to par with the investment from the government. Imported technology which can be adopted to local advantage is encouraged together with the strengthening of indigenous capability in science and technology. With past confidence, the government is aiming at promoting comprehensive research to serve its development strategy.

The level of sophistication in science and technology in the Republic of Korea can best be validated by the nature and scope of spin-off specialized research institutes now existing in the country, viz.

/ - Standards

- Standards Research Institute
- Shipbuilding Research Institute
- Chemical Technology Research Institute
- Energy Conservation and Management Research Institute
- Nuclear Fuel Development Institute
- Heavy Electrical Equipment Testing Institute
- Telecommunications Research Institute
- Machinery and Metal Testing Research Institute
- Electronics Research Institute
- Ocean Research and Development Institute
- Solar Energy Research Institute

<u>Salient Characteristics of the Republic of Korea Programme on Science and Technology</u>

As stated in the national report to the UNCSTD conference, "One essential facet contributing to the success of the Korean science and technology programme is the fact that the country's top policy-makers as well as legislators recognize the need for scientific and technological development and consequently push hard for such development plans to the extent of establishing a separate article in the Constitution for the development of science and technology as a mandatory duty of the government in advancing the nation's economy and welfare."

Proper organizational structure is vital to the success of science and technology development. In observing the case of the Republic of Korea, it should be borne in mind that the policy in Korea is on industrial development for exporting, while agricultural development is mainly for self-sufficiency in food production. The stress is definitely on the former. Nevertheless, the all-out effort and the action-oriented programme of the Korean Government are well worth emulation.

/PALM OIL

PALM OIL MILL EFFLUENT MANAGEMENT IN MALAYSIA

Water pollution problems have received high priority in Malaysia. This is due to the deteriorating condition of water bodies, particularly rivers in the country. It was estimated that the total discharge from oil palm mills is more than 500,000 lbs. per day, from more than 130 mills. This load is expected to be doubled by 1980.

Government Measures

Realizing the seriousness of this problem, the Malaysian Government established the Division of Environment (DOE) in 1974. From the outset, this dynamic body stressed pollution control, particularly the improvement of effluent quality from palm oil mills. DOE now consists of more than 90 technical staff with an annual budget of more than M$ 22 million. Its main function is enforcement and regulation. For water pollution control, the approach is to utilize discharge standards. A stage-wise improvement in effluent quality has been imposed which is expected to improve the quality of palm oil mill effluents from 20,000 BOD down to 500 BOD in four years. Table 1 illustrates the parameters and the expected quality according to the planned timetable. At the same time, a fee is being imposed based on the amount of discharge into the receiving body and whether it is discharged into a water course or on land, according to the following rates :

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Table 1 Effluent standards for palm oil mills

Parameters	Standard A 1.7.78	Standard B 1.7.79	Standard C 1.7.80	Standard D 1.7.81
Biochemical Oxygen Demand (BOD), 3-day, 30°C; mg/l	5,000	2,000	1,000	500
Chemical Oxygen Demand (COD); mg/l	10,000	4,000	2,000	1,000
Total Solids; mg/l	4,000	2,500	2,000	1,500
Suspended Solids; mg/l	1,200	800	600	400
Oil & Grease; mg/l	150	100	75	50
Ammoniacal-Nitrogen; mg/l	25	15	15	10
Organic-Nitrogen; mg/l	200	100	75	50
pH	5.0-9.0	5.0-9.0	5.0-9.0	5.0-9.0
Temperature, °C	45	45	45	45

Source: Division of Environment, Malaysia, September 1979.

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(a) A basic rate of M$ 10 per metric ton of BOD applicable to all licenses;

(b) An excess rate of M$ 100 per ton BOD for effluent concentration exceeding the limit in (a). For example, under the first year of enforcement any amount of effluent exceeding 5,000 mg/l will be charged according to this rate;

(c) A basic rate of M$ 50 per 1,000 tons of effluent disposed on land applicable to all licences;

(d) An excess rate of M$ 100 per ton of BOD for those concentrations exceeding the limit in (c).

Under this enforcement scheme, DOE has succeeded in encouraging the installation of treatment facilities in palm oil mills. It is estimated that by the end of 1979 about 60 to 70 per cent of the mills will have installed treatment systems. As for new mills the licence will not be issued unless a proper treatment system is incorporated. Under its first year of operation almost M$ 2 million in fines had been imposed.

Recently, the Malaysian Government has established a new Palm Oil Research Institute of Malaysia (PORIM). This is an autonomous state enterprise under the Ministry of Primary Industries. Although it is in its inception stage at the moment, it has the potential to be fully developed comparable to the successful Rubber Research Institute of Malaysia. PORIM will also be able to generate its own fund through the levy based on palm oil production.

Salient Characteristics of the Malaysian Approach

The success of the Malaysian programme on water pollution control for palm oil effluents may be attributed to :

(a) The dynamic role of the responsible agency which has competent young staff members who are conscious of the pollution problems of the country;

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(b) The high degree of collaboration among governmental agencies. A case in point is a recent agreement among DOE, the Standards and Industrial Research Institute of Malaysia (SIRIM) and the Chemistry Department. DOE will now concentrate on the regulatory functions, whereas technical research and advice will be provided by SIRIM. At the same time, the Chemistry Department assumes the laboratory work. This kind of distinct division of responsibility and labour is vital to a successful governmental programme and contributes to the productive and concerted effort of the Government.

(c) The role of the private sector: the private sector should be regarded as the wheel which keeps the economy rolling. In this regard,the palm oil industry has fulfilled its role in collaborating with the Government on its pollution control programme. Some of the mills have set up their own environmental units responsible for the improvement of the quality of their effluents and the utilization of effluents for multifarious purposes. This perhaps is due to the profitable market condition at the moment. It is more opportune for government to seek collaboration from the private sector while the industry itself is able to afford the associated costs, because it will be more willing to invest in pollution control euqipment.

As pointed out in the earlier chapter, pollution control should, particularly for agro-industry, be considered only as a last resort. The Malaysian Government is fully aware of the potential of residue utilization and has looked into various applications of palm oil effluents such as for land irrigation and animal feed. In the future, with the full establishment of PORIM, the fund generated by PORIM should be used for the purpose of promoting residue utilization into viable commercial applications with full participation from the private sector.

There should be a cost-effectiveness analysis of various standards imposed by the DOE. At the moment, there is a major research project funded by IDRC and executed by the Asian Institute of Technology. The objective is to investigate the most practicable and appropriate technology

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for the treatment of palm oil effluents. A cost-effectiveness study will provide an additional dimension which will serve the government in directing its policy regarding standards. The government itself fully realizes that unified standards for all receiving water bodies are not the best solution since the assimilative capacity of the environment has not been taken into consideration. For example, a palm oil mill situated in Sabah or Sarawak may not necessarily pollute the river in those areas, whereas an additional mill on a highly polluted river in Peninsular Malaysia may deteriorate the water quality beyond its threshold. Hence, a cost effectiveness study may contribute to the improvement of effluents standards appropriate for local conditions.

IV RECOMMENDATIONS FOR THE FUTURE

As hopefully brought out in the previous chapter, there is great potential for residue utilization in this region. In fact, residue utilization not only leads to more efficient use of available resources but also serves in controlling pollution from agricultural and agro-industrial sources.

At the time being, much of the utilization of residues for commercial applications are still in the developmental stage. Hence, more governmental support and recognition of this potential is needed particularly in financing and initiating research programmes being carried out by various research institutes.

NATIONAL LEVEL

The development of a national organizational structure depends on the political, social and economic development of each particular country. In certain cases during the mission, it was observed that a proliferation of governmental agencies was detrimental to development. Again, emphasis must be placed on interagency co-operation. On the issue of residue

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utilization, it is necessary for such a collaboration to be extended to the private sector.

Due to the multidisciplinary nature of residue utilization which requires scientists from various disciplines such as chemistry, chemical engineering, food technology, agricultural engineering, mechanical engineering, environmental engineering, microbiology, biochemistry, biotechnology, economics, social science, agricultural science, food science, agronomy, animal physiology, nutrition, entomology, there seems to be a sufficient existing pool of local manpower. What is needed is the reorientation of their interest and the strengthening of the training programme to increase their technical capability.

There is no need to set up new institutions. National efforts can best be served by designating a central agency among the already existing ones. This agency may serve as the information centre responsible for disseminating up-to-date information on the state of the arts of various methodologies for residue utilization to other related agencies. For some countries, it may be worthwhile to explore the benefit of creating an interagency committee on such a topic. At the same time, the organization of national seminars have proved valuable. The recent preparatory meetings at the national level organized for the United Nations Conference on Science and Technology for Development have confirmed the benefit of establishing a national policy supportive to the development and the promotion of residue utilization.

Those which are regarded as residues at one time may serve as vital raw materials at others. This is the case with the recent interest in producing fuel alcohol from sugarcane, molasses and tapioca. There are definite plans of the governments of the Philippines, Thailand and Papua New Guinea to move into this alcohol fuel production mainly for transportation. In the Philippines, the government national alcogas programme calls for the construction of ten distilleries by 1986, requiring an investment of more than 2.8 billion Peso.

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Organizationally, the designated central agency on residue utilization should not be involved in implementing the utilization of residues itself. It should play the catalytic role in planning for residue utilization, ensuring that the potential of residue utilization is exploited to the extent possible by other related agencies including the provision of sufficient funds for research and pilot testing, dissemination of research results to the private sector together with economic feasibility studies.

On the environmental front, treatment should be considered as the last resort. Process improvement and residue utilization could enhance the economic benefit of the industries. Concurrently, technical guidance whenever necessary should be provided to small industries which are not able to absorb the financial investment for pollution control. The regulatory programme of the government should not, however, be based solely on enforcement since co-operation rather than confrontation is the prevailing attitude in developing countries of Asia and the Pacific.

INTERNATIONAL LEVEL

From the mission, it is surprising to observe the lack of information exchange among developing countries. This must be strengthened. As for the transfer of information from developed countries, the examples of the Philippines which has set up scientific missions in selected capitals of developed countries or the case of the liaison offices on science and technology established by the Republic of Korea, should be emulated.

The on-going project on the Management and Utilization of Food Wastes Materials of the ASEAN countries with the financial support from Australia under the ASEAN-Australia Economic Co-operation Programme (AAECP) may serve as an outstanding example of international collaboration on residue utilization. This project, with the total budget of A$ 2.5 million, draws upon the strength of various research institutes existing in the ASEAN countries. Research will be carried out with the objectives to develop fermentation process and the production of biogas from cellulose

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materials. Secondly, the development of membrane technology of reverse osmosis and ultrafiltration in the treatment of food wastes will be carried out. The scope of work covers laboratory research and pilot plant to ensure the technical and economic feasibility of the research itself. Proposed research includes the study of extraction of carotenes (pro-vitamin A) from crude palm oil and the production of antibiotics through aerobic fermentation of agricultural products.

In this connexion, the role of international research institutes such as the Denver Research Institute which has set up a network on non-conventional energy technology for rural and village areas, linking with the Philippines National Institute of Science and Technology, Thailand's Institute of Science and Technological Research, Indonesian Institute of Science, Standards and Industrial Research Institute of Malaysia, Korean Institute of Science and Technology should be commended.

A network of major research institutes of developing countries should be established. This network may also include selected institutes from developed countries which are interested in international collaboration on residue utilization such as the CSIRO of Australia, Denver Research Institute, and Georgia Institute of Technology. Annual meetings should be organized both at the administrative level to exchange experience regarding the promotion of residue utilization, and at the technical level where intellectual cross-breeding and technology transfer could take place. In carrying out this programme, technical and financial input from multilateral and bilateral sources such as UNEP, FAO, UNESCO, ESCAP, USAID, and Australia should be mobilized.

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MAJOR REFERENCES

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COMMERCIALIZATION OF RESEARCH RESULTS
ON
AGRICULTURAL AND AGRO-INDUSTRIAL RESIDUE UTILIZATION

COMMERCIALIZATION OF RESEARCH RESULTS

ON

AGRICULTURAL AND AGRO-INDUSTRIAL RESIDUE UTILIZATION

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I INTRODUCTION

In most developing countries, including Thailand, large quantities of residues from agricultural and agro-industrial activities are discarded annually as wastes. Disposal of these wastes is a burden to the industry and improper disposal results in pollution of the environment.

Many kinds of residues that are normally regarded as waste products have good potential as raw materials for other valuable processed products. Examples of such wastes are sugarcane bagasses, cassava residues, corn cobs, husks of various crops such as rice, cotton and peanuts. These, if properly utilized, may serve as supplemental raw materials for industry and as renewable resources for much needed products, i.e. food, feed, fuel and fertilizer. It is believed that the demand for these products grows at an increasing rate in most, if not all, developing countries.

Increasing attention has been paid to the productive and effective utilization of wastes, particularly of agricultural and agro-industrial sources. Processing technologies for utilizing many of the above-mentioned agricultural and agro-industrial residues are available on the world market. Some have already been successfully introduced in a number of developing countries, in most cases, with necessary adaptation so

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that the technology adopted is practically suitable for various types of raw materials and the environmental socio-economic conditions found in developing countries. Some technologies have been researched and developed locally within the countries as innovative indigenous technology.

The present paper discusses the introduction and/or application of certain residue transformation activities in Thailand, with particular emphasis on the commercialization aspects of development. Two case studies are presented to elaborate key issues discussed in the text and also to serve as material for further discussion on the basis of practical examples.

II NEED FOR TECHNOLOGY DEVELOPMENT

Generally speaking, most developing countries depend, to a large extent, on the scientific and technological knowledge generated or developed in industrialized countries. Research and development activities in less developed countries often consist of imitative quasi-research with little progress in technological innovation, particularly in the fields of industrial technology. Even in the fields of agricultural and agro-industrial waste utilization in which relevant and competent, locally suitable indigenous research and development is badly needed, efforts have been inadequate to help solve the problems of waste recovery and environmental pollution.

The need for technology for waste utilization is normally established when the industry is faced with one or more of the following problems or factors :

a. Recognition of the problem for the existing operation; such as inadequate supply of raw materials, etc. A good example is found in the case of the vegetable oil industry. Many vegetable oil processing plants are forced to discontinue operation due to lack of supply of raw

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materials. Realizing the potential availability of several unutilized seeds for the source of raw material, a research programme can be developed to seek additional sources of raw materials for the vegetable oil industry - rubber seeds, rambutan seeds, etc. Studies are necessary to develop suitable processes for pretreatment and extraction of oil from different variety of seeds. The process needed is the one that requires minimum modification of existing plants and application for a variety of seeds.

Another example is the need for a substitute for peat to be used in the production of fertilizer for legumes. Peat is available in the south while legumes are mainly cultivated in the north and transportation of peat from the south to the north for such purpose, though possible, is not economically feasible. In this case, however, investigations have revealed that a filter cake waste produced by sugar factories can be used as a substitute. Only pretreatment and slight modification of existing technology are necessary.

b. The realization of business opportunity

In the papaya production industry, only a small amount of latex is extracted from the papaya skin. The remaining whole papaya is discarded as residue. Realizing the opportunity for producing a highly acceptable processed product based upon preliminary laboratory investigations, a research contract with a research and development (R & D) institution can be secured to develop a process for large-scale production of a papaya-based product.

c. Legal pressure requiring technological changes

With the increasing pressure from the Government to curb pollution generated by industries, there has also been a corresponding increase in the need for residue and waste treatment and utilization. Efforts to recover as much as possible make it more attractive for industry to adopt productive utilization technology whenever feasible rather than to carry out just the treatment of wastes where profitable

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return is nil.

To acquire the required technology, an entrepreneur has two alternatives, i.e. either to purchase the technology from abroad, often in the form of consultancy or hardware, or from local R & D institutions. It is unfortunate that, in practice and in most cases, the entrepreneur prefers to choose to purchase the technology from abroad.

III CONSTRAINTS IN COMMERCIALIZATION OR RESEARCH RESULTS

There are several reasons for the slow commercial adoption of developed technology in the field of agricultural and agro-industrial waste utilization by the private sector. The constraints experienced in Thailand, as well as in most other developing countries are both of a technical and a non-technical nature.

a. Need for integration of science and technology in development planning

For local, indigenous R & D institutions to achieve successful application of research results, one cannot treat R & D in isolation. Consideration must also be given to other factors such as :

(i) the productive system - which, among other things, must be oriented to the reception of locally generated technologies and know-how;

(ii) the socio-cultural conditions of the people and/or the community;

(iii) the education and training process to provide skilled workers and technologists;

(iv) the social and environmental impacts of R & D;

(v) the consideration of science and technology and their application in the context of economic development.

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b. Need for policy instruments

In the area of management and development of natural/renewable biological resources including agricultural surpluses and residues, a policy decision at the national level and effective implementation must be made, keeping in mind the long-term benefits therefrom. Without such a policy, very little progress can be expected in the field of wastes/residues utilization/treatment since pollution control in most forms is, generally speaking, expensive with little, if any, direct profitable return in most cases.

c. Preference for foreign-generated technology

Up to the present time, the pattern of research and development in Thailand has largely been one of supporting the transfer of know-how from more developed countries. This is true in spite of the fact that Thailand has several research and development divisions in various ministries dealing with development as well as in most, if not all, universities.

In view of the present common practice of importing technology from abroad, it is anticipated that as pollution control efforts increase private expenditures for imported technologies (equipment and/or consultancy) will be substantially higher causing an unnecessary drain on foreign currency supply. For this season, technologies should be encouraged to be developed and equipment manufactured locally with strong support from the government.

d. Counterproductive science and technology policies

Science and technology consist of a broad spectrum of activities and, as such, can be affected by other non-related policies in force. Isolated actions are sometimes found to be nullified by counterproductive non-science and technology policies which encourage directing the already weak domestic demand for technology more and more toward external sources. One example is the policy promoting importation of technology/equipment by providing tax/custom excempt privileges on

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imported hardware and other privileges for foreign technical consultants without giving due consideration to existing, locally available technical expertise and capability.

e. Lack of effective linkages

Whatever research and development efforts are made locally, they are often wasted or not utilized by the commercial/industrial sector. The main reason being the lack of effective links between research and development activities and productive commercial systems. The weakness of these linkages, consequently, leads to a lack of communication between the demand for, and the supply of, locally produced technical knowledge and know-how.

In the case of Thailand, this shortfall is due to the fact that the demand of the productive systems, both public (government) and private, for technical know-how is largely satisfied from importation from developed or more advanced countries. Large enterprises prefer to import technology from developed countries such as Japan, the United States of America, Federal Republic of Germany, and the United Kingdom of Great Britain and Northern Ireland while small ones prefer to buy from areas and countries such as Hong Kong and others in Asia.

It might be of interest to mention that Thailand has experienced some unfortunate incidences with regard to the transfer of technology from abroad, particularly technologies in the form of hardware. One example is the purchase of conventional sewage treatment technology from a western country. Included in the hardware package was a sludge digester equipped with a heating (and not cooling!) system, designed to keep the temperature in the range of around 35°C. This purchase was an unnecessary loss to the local company as well as to the country.

Another example involves the purchase of a very old plant that was not suitable for further industrial use after less than two years of operation; that is, machines started to fall apart and spares could not be obtained.

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f. Unattractive business opportunity

Waste utilization, as a business operation, is generally unattractive. Successful operations to date have dealt mainly with either an integrated operation, where loss in one activity can be compensated by the other, or as a pollution control measure.

Consequently, it is more difficult for these operations to receive favourable consideration for loans from financial institutions.

g. Lack of confidence in local R & D capability

The commercial sector's preference for imported technologies is due to their belief that the use of foreign-originated technology involves less risk at the enterprise level than experimenting with locally developed technology. To them, the import of technical know-how is relatively more convenient and seems more profitable than unproven locally developed knowledge and technologies.

h. Lack of interest/understanding the value of R & D

In general, there has been very little interest on the part of the commercial sector in research and development. Very few industries have funds available for applied research and technological development. In most cases, these effects are found in joint venture enterprises with foreign-based parent companies where the main research and development activities are normally undertaken. In Thailand it is also not uncommon to find that an industry, particularly a small indigenous one, is often unsophisticated or has very little or no understanding of the value and importance of technical development in the improvement of their processes or products or operations.

i. Long time lag for R & D

Lastly, the fact that a considerable time lag between initiating an R & D programme and the results it obtains for practical adoption is indeed very discouraging for local industry.

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IV COMMERCIALIZATION OF RESEARCH RESULTS

Technology transfer can be promoted in different ways, i.e. information dissemination, consultancy services, and setting up of pilot projects to test and/or demonstrate designs in local situations.

Commercialization of the transferred technology comprises not only the adaptation of technology but adoption of the adapted technology for practical implementation as a commercial operation. In other words, it may be said that commercialization of technology is putting technology to use in a business context under local conditions.

Several steps are involved before any technology or process can be commercialized :

- Generation/Development of Know-How
- Testing of Technology
- Technology Transfer
- Modification and/or Adaptation of Technology
- Adoption of Technology for Practical Applications

In view of the limited financial and human resources normally found in most developing countries, applied research work to generate technology should be undertaken and encouraged only when it is clear that there is likely to be a case for the commercial exploitation of the research result. It is important that relevant techno-economic questions be carefully studied before the actual practical work is started.

Pilot plant operation, for testing the design or gathering necessary technical (chemical engineering) data for more detailed economic assessments and/or for the eventual design of commercial-scale plants, is normally rather expensive. Therefore, it is necessary to carefully consider and determine the real need for such work.

In Thailand, where there are numerous small-scale agricultural and agro-industrial operations, the adoption of imported waste/residue

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utilization technologies and the need for pilot testing are relatively less than in countries with large-scale plants. In many cases, it has been found that the data or information already available in the published literature are adequate. Examples are the production of vinegar from pineapple wastes and coconut water, and the utilization of rice straw and saw dust for mushroom cultivation.

In msot other cases, necessary data can be and have been obtained by using merely large laboratory-scale equipment or only one section of a pilot plant. Examples of this approach are the commercial development of a coconut cream plant processing a maximum of 5 tons of coconut meat per day, and the production of (microbial/rhizobia) fertilizer for legumes from coconut coir dust.

However, pilot plants are sometimes necessary for obtaining valuable technical and economic data. At other times, pilot operation is needed for demonstration and/or promotion purposes. Promotion of biogas generation is such an example.

Generally speaking, the objectives for carrying out a pilot study are :

(i) To gather technical (engineering) data required for detailed and more reliable economic assessments of the technology/ process to be commercialized.

(ii) To determine additional technical parameters/data needed for the design/manufacture of commercial-scale plants;

(iii) To test and/or demonstrate the design/technology developed or adapted;

(iv) To manufacture small quantities of anew product for acceptability and/or market testing.

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V. FACTORS ENHANCING SUCCESSFUL COMMERCIALIZATION OF RESEARCH RESULTS

The commercilization of research results for practical commercial application is a very complex process involving not only research and technological development but also economic, social, cultural and political inputs.

a. Government support for indigenous technological development

The Government of Thailand has been fully aware of the potential application of science and technology for national development. In 1963, the Government specifically established a research and development institution to serve as the main centre for applied scientific and technological research. The institution was formerly known as the Applied Scientific Research Corporation of Thailand. With the recent (1979) establishment of the Ministry of Science, Technology and Energy, the institution's name has been changed to become Thailand Institute of Scientific and Technological Research (TISTR). The change in name signifies TISTR's role as the main national research and development agency.

One of the main functions of the Institute has been to initiate, carry out and promote scientific and technological research as well as to apply research results for practical application (commercialization) in relation to the maximum utilization of the country's natural resources and environmental management capacity including waste treatment and utilization.

b. Good institutional arrangement

To allow for maximum efficiency (flexibility) in carrying out its tasks, particularly with regard to the commercialization of research results, TISTR has been legally granted a special status by being made a semi-autonomous body operating outside the civil service. This makes it possible for TISTR to establish direct linkages with research institutions in other countries and to carry out research and development work

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for the private sector on a contract and confidential basis. Other important features are :

(i) TISTR selects and monitors each research and development programme from both commercial and economic viewpoints so that it can detect as early as possible flaws in the viability of the programme;

(ii) Research and development is carried out by multidisciplinary teams drawn from various groups, as appropriate, of professionals and, if and when necessary, with outside assistance, i.e. private firms, universities, etc.

c. Science and technology at the highest governmental level

The recent establishment of the Ministry of Science and Technology will undoubtedly help in strengthening the position of TISTR, for good institutional arrangements (when they exist) can facilitate the contacts between parties, i.e. R & D institutions and the Government. Putting science and technology at the highest (ministerial) level is considered a good arrangement.

d. Government support on policy instruments and incentives

From the experience of Thailand, there are indications that given adequate technical/financial support and incentives, and with necessary policy decisions, the private sector is willing to take advantage of less expensive, locally developed know-hows and technologies. Specific examples illustrating this point is the case of the establishment of a coconut production plant (Case Study No. 2).

VI SUCCESSFUL CASES OF COMMERCIALIZATION

In cases where pilot studies have been successfully carried out and eventually commercialized for practical application, one or more of the following factors are believed to play an important role :

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(i) Research and/or the pilot work was sponsored by the client;

(ii) In the case where research had not been sponsored by a client, efforts were successfully made to persuade the client to sponsor a pilot-scale phase, or at the very least, to persuade the industry to share the cost either in cash or in kind;

(iii) Consent was obtained from the industry to construct a pilot plant on its premises using wastes from their existing plants as raw material;

(iv) Construction of the pilot plant was carried out in close collaboration with chemical engineer(s) employed by the industrial client.

(v) Technology required by the industry is not available on the world market or the raw materials to be used are unique for the country. This is normally found in the case of processing technology for medicinal plants. A specific example is illustrated in the coconut plant case study.

Experience indicates that such joint developments not only help to ensure smooth transfer of technology from the research institution to industry but is also of much value to the institution in enabling it to obtain a better appreciation of industrial problems, thus gaining more industrial experience. There have been few instances where it was found necessary by the research institution to carry out the pilot operation without industrial encouragement or financial support.

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VII THE POTENTIAL ROLE OF THE PRIVATE SECTOR, INCLUDING VOLUNTARY NON-GOVERNMENTAL AGENCIES

After what have been mentioned about the Government's role, the natural reaction at this point is to blame the Government. But are these ineffectivenesses the fault of the Government? The answer is no. With limited financial resources and other economic and political constraints, it is not possible for the Government to provide adequate resources in favour of R & D development while other more immediate needs are to be solved.

It is strongly believed that by collaborating between the Government on the one hand and the private and commercial sector on the other, an effective R & D transfer mechanism/system for practical application can be established.

The following will help strengthen the points mentioned :

a. The private sector, i.e. industry should set aside a small percentage of income as expenditure for R & D.

b. Whenever feasible and possible, industry should maximally use locally manufactured equipment.

c. Whenever appropriate, the private sector should preferentially utilize local technical expertise.

d. Private industry should encourage their technical staff to receive further technical training for better understanding of the value of R & D.

e. Financial institutions should be made increasingly aware of the value of R & D and its role in promoting commercialization.

It is also felt that private, non-governmental organizations (NGOs), several of which are involved in one way or another in national development, particularly at the village level where the majority of people live, can co-operate with the Government. In view of the fact that many of

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these organizations work at the grass-roots level where the Government's outreach system may not be able to reach, it is believed that they can act as an extension network of change agents assisting in non-formal training for disseminating appropriate technologies. Increasing co-operation between Government and NGOs is therefore desirable. NGOs should also be given more opportunity and encouraged to help the Government in development activities. This task will not be technologically too difficult in view of the fact stated earlier that many successful and practical applications of results/technologies for small-scale utilization of agricultural residues involves only dissemination of information to create awareness among the rural people.

Consideration should also be given to the role international agencies can have in promoting the commercialization of research results. In this case, preference for local expertise and consultancy should be encouraged whenever feasible.

VIII CONCLUDING REMARKS

In Thailand, with its population increasing not only from its continuing high rate of population growth of 2.3 per annum but also from refugees flowing into the country at an alarming rate, it is highly desirable to mobilize the combined efforts of the government, the commercial sector, and even the general public in increasing the efficiency of utilization of the country's renewable resources including wastes. This is necessary in order to assure sufficient availability of supplies, at reasonable prices, which will not cause social and economic hardships to the nation. Moreover, utilization of wastes can also serve as a sanitary measure to improve and maintain the health standards of the country.

The effective commercial utilization of agricultural and agro-industrial residues for productive ends deserves greater attention and financial support from both the public (government) and private sectors.

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It is also necessary to realize by all concerned, particularly those involved in the transfer of technology, that the choice of technology for processing wastes in order to return economically beneficial net results does not necessarily imply the importation of high-cost technologies and/or engineering packages from abroad. In many cases, the effective and productive utilization of agricultural residues can be achieved with a small-scale, simple technology which is utilized at the village level and which requires no specialized tools. The widespread use of green fodders and the making of compost needs only effective dissemination of information. In these cases, it is not so much technology as it is awareness of what is being transferred. In other cases, a simple locally manufactured compression/pelletizing machine can be installed on site in the fields and on the farms for use in converting agricultural residues into feed pellets.

For more complicated technologies, it is advisable for potential users to consult local R & D institutions such as the Thailand Institute of Scientific and Technological Research for information and/or technical assistance about choices and development/adoption of technologies for commercial application. The import of technology from abroad for commercial application in Thailand, if and when necessary, can be effective and successfully carried out if suitable policies and guidelines are provided by the Government.

Finally, the understanding and co-operation by financial institutions need to be strengthened to obtain necessary financial support for commercial-level operation.

CASE STUDY NO. 1

The Commercialization of a Biogas Digestor for Piggery Wastes

A. THE PROJECT

A biogas generator was developed by a local university using locally available materials. Simple construction and manufacturing techniques were also developed that can be carried out by villagers having little technical skills.

B. THE PROCESS

A pilot biogas digestor unit was constructed by a team of locally skilled workers, i.e. blacksmiths, bricklayers and masonaries under the engineering supervision of a R & D team. The site selected for the demonstration, the construction as well as the operation of the biogas digestor was at the house of a community leader/change agent who has participated in the project's development which was aimed at promoting appropriate technology development for the community. The pilot operation site was opposite to the village school.

C. THE PROMOTION

Once the construction was completed and ready for operation, students and teachers were encouraged to participate in the project. They were asked to bring from their homes hog and chicken manure in plastic bags provided by the project. Those who contributed regularly were provided with token certificates which could be exchanged for a small sample amount of gas which was contained in used truck tyre tubes, for experimental use in their own homes.

D. THE RATIONALE

The rationale and objectives of the project are as follows :

1. The slow adaptation of biogas digestors, up to the present time, by villagers is due to the lack of information and understanding of the scientific and technological background of the process.

2. An opportunity is provided for villagers and potential users to participate, conceive new ideas and be familiar with the technology in their own environment.

/3.

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3. The application of the biogas digestor has dual purposes, i.e. of improving sanitary conditions by eliminating polluting wastes from pig pen areas and of providing an alternative source of fuel (biogas) reducing the need to cut down wood from the nearby forests.

E. THE RESULT

After two months of operation and demonstration, eight applications for technical assistance were received. A revolving fund has been set up to provide loans and local skilled workers have been selected for additional training to expand pilot operation into commercial operation.

F. REMARKS

It should be emphasized here that commercialization in this case is a combined process of disseminating information, creating awareness, enhancing motivation and spreading technical consultancy services. Biogas technology has long been established but successful commercialization of the technology, particularly in Thailand, has not yet fully been accomplished. In this case, non-technical factors play more important role than technical ones.

CASE STUDY NO. 2

The Integrated Coconut Processing Plant

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A. THE PROJECT

An industrial client approached a research institution to help solve the pollution problem faced by his coconut meat processing plant which produces large quantities of liquid wastes (coconut water).

The institution suggested that the client participate in its on-going laboratory-scale integrated R & D programme (in-house project) to produce coconut cream as a nucleus product to enable the collection in sufficient quantities of other waste by-products for further processing into highly valued products.

B. THE PROCESS

An agreement was reached between the client and the R & D institution, to carry out the following tasks under the financial sponsorship of the client :

1. An improvement of a large-scale laboratory facility to gather additional necessary technical data.

2. The production of small quantities of the product for acceptability and market testing.

3. The scaling-up of the pilot (large-scale laboratory) operation including its design and plant construction.

4. The negotiation with government authorities concerned for favourable consideration in obtaining a plant license, food quality certificate, etc.

C. THE RATIONALE

1. The production of the cream alone is not economically feasible.

2. The technology developed makes it possible to gather large enough quantities of liquid and solid coconut residues for further processing into other useful products, such as activated charcoal from

/husks,

husks, vinegar from coconut water, coconut flour from meat residue, etc.

3. The acceptability of one technology leads to potential acceptability of other technologies to be developed gradually.

4. Confidence in local R & D capability is developed once the linkage, understanding and communication are established.

RESIDUE UTILIZATION - MANAGEMENT OF AGRICULTURAL & AGRO-INDUSTRIAL RESIDUES OF SELECTED TROPICAL CROPS (INDIAN EXPERIENCE)

RESIDUE UTILIZATION - MANAGEMENT OF AGRICULTURAL & AGRO-INDUSTRIAL RESIDUES OF SELECTED TROPICAL CROPS (INDIAN EXPERIENCE)

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I INTRODUCTION

Increasing population, rapid industrialization and expanding urbanisation have increased our needs manifold. These phenomena have combined to create shortages of raw materials for industry and inputs for agriculture. The energy crisis has aggravated the situation still further. The continued import of materials by developing countries not only drains their valuable foreign exchange reserves, but also creates a sense of perpetual dependence on outside sources, ultimately stifling the urge for initiative. These problems can be solved only through maximum and efficient utilization of resources indigenously available in the country. Development of new patterns of utilization through optimum use of the latest scientific and technological advances cannot only provide an array of useful economic products but also open up vast possibilities of employment, reduce the cost of production, provide rich dividends to the farmer, solve disposal problems, minimize pollution hazards and ensure balanced ecological growth.

The main problems in the utilization of agricultural and agro-industrial residues are: their scattered availability and bulky nature, resulting in collection and transporation problems; uneconomic alternative uses lack of appropriate technology and consultancy services; and difficulties in marketing of finished products.

/The

The potential importance and scope of organic residues as an inexhaustible store of valuable economic products has been well realized. The report 'Utilization and Recycling of Wastes' brought out by the National Committee on Science and Technology, Government of India, New Delhi clearly indicates the variety of residues available in the country and the diversity of end-products derivable therefrom. Various R & D institutions working under the aegis of the Indian Council of Agricultural Research, Council of Scientific and Industrial Research and some Agricultural Universities are actively engaged on various research projects relating to the recycling of residues.

Intensive production and processing methods have created problems of residue management. These problems can be broadly classified under two groups: (1) under-utilization of the available resources, and (2) environmential hazards. The FAO/UNEP Seminar on Residue Utilization-Management of Agricultural and Agro-industrial Residues held in 1977 stressed the urgent need to use and develop environmentally sound technologies adapted to and compatible with the economic, social and political situations.

The present paper highlights the Indian experience pertaining to the management of residues available from rice, sugarcane, maize, coconut, tapioca, oil palm and rubber, some important crops of South and South East Asian countries. The utilization pattern is discussed from the point of view of energy, industrial chemicals, constructional materials, architectural boards, pulp and paper, animal feed and organic manures.

In order to provide an insight into the magnitude of the work done on various aspects of this problem in India, a supplement has been added in the form of a bibliographical survey of literature. The approach to be adopted for future programme of work is discussed under 'Concluding Remarks'.

Keeping in view the numerous limitations inherent to a survey of this type, the present paper is intended to serve only as a 'Working Paper' for detailed discussions residue-wise so as to draw a realistic plan for implementation.

II

II RICE (Oryza sativa)

Rice is the major cereal crop of India covering an area of about 40 million hectares - the largest area under any single crop. Next to China, the country is the second largest producer of rice in the world. Rice Milling, with a present turn-over of more than 6,000 crores per annum, is the most important agro-based industry, with a total number of 88,730 rice mills.

During the milling of rice, husk and bran are obtained as by-products. Rice bran on extraction yields bran oil and deoiled bran. Straw is available in the form of crop residue. An estimation of the potential availability of residues-husk, bran, bran oil, deoiled bran and straw during 1977-1978, State-wise, is presented in table 1. There was a significant increase in rice production and availability of residues during 1960-1961 (68.0%), 1970-1971 (106.3%) and 1977-1978 (156.0%) in comparison to 1950-1951 as the base year (table 2).

2.1 Rice Husk

a. Availability: Husk comprises of about 1/3 of clean rice. From 52.7 million tonnes of clean rice produced in the country during 1977-1978, the quantity of husk available would amount to 17.6 million tonnes (table 1).

b. Composition and Characteristics: The chemical composition of rice husk tends to differ according to the variety, the location and the efficiency of the hulling process. The husk contains about 40% crude fibre, 25% nitrogen free extract and 20% mineral matter with small quantities of crude protein and other soluble extract. Rice husk ash is rich in silica which amounts to about 95%. Unlike other plant parts, rice husk shows unusual physical and chemical properties:

- i) High ash and high silica content.
- ii) Peculiar silica-cellulose structural arrangement.
- iii) Fragile and porous nature.
- iv) Short fibre length.
- v) Low nutritional and manurial value.

/ Table 1

Table 1 Potential availability of rice by-products and straw during 1977-1978 ('000 tonnes)

State	Rice	Husk	Bran	Bran oil	Deoiled Bran	Straw
West Bengal	7508.7	2502.9	450.5	81.1	369.4	14079
Tamil Nadu	5901.0	1967.0	354.0	63.7	290.3	11064
Bihar	5518.6	1839.5	331.1	59.6	271.5	10347
Andhra Pradesh	5299.2	1766.4	317.9	57.2	260.7	9936
Uttar Pradesh	5141.8	1713.9	308.5	55.5	253.0	9641
Madhya Pradesh	4395.0	1465.0	263.7	47.5	216.2	8241
Orissa	4319.2	1439.7	259.2	46.7	212.5	8098
Punjab	2794.0	931.3	167.6	30.2	137.4	5239
Maharashtra	2344.0	781.4	140.6	25.3	115.3	44395
Assam	2284.0	761.3	137.0	24.7	112.3	4282
Karnataka	2280.7	760.2	136.8	24.6	112.2	4276
Kerala	1269.4	423.1	76.2	13.7	62.5	2380
Haryana	964.0	321.3	57.8	10.4	47.4	1808
Gujarat	669.3	223.1	40.2	7.2	33.0	1255
Other States/ Union Territories *	1987.5	662.5	119.2	21.5	97.7	3727
ALL INDIA	52676.5	17558.6	3160.6	568.9	2591.7	98768

* Tripura, Jammu & Kashmir, Manipur, Rajasthan, Meghlaya, Himachal Pradesh, Arunachal Pradesh, Nagaland, Andaman & Nicobar, Dadra & Nagar Haveli, Delhi and Pandicherry.

Table 2 Rice production and potential availability of residues from 1950-1951 to 1977-1978

Year	Rice	Husk	Bran	Bran Oil	Deoiled Bran	Straw
1950-1951	20,576	6,859	1,235	222	1,013	38,477
1960-1961	34,574	11,525	2,074	373	1,701	64,653
1970-1971	42,448	14,149	2,547	458	2,089	79,590
1977-1978	52,676	17,559	3,161	569	2,592	98,768

<u>Conversion ratios used:</u> Husk - 1/3 clean rice, Bran - 6% clean rice, Bran oil - 18% bran, and Straw - 1.875 times clean rice.

<u>Source:</u> Estimates of Area and Production of Principal Crops in India 1970-1971 and 1977-1978. Directorate of Economics and Statistics, Ministry of Agriculture and Irrigation, Government of India, New Delhi.

These unique characteristics confer on rice husk certain distinct advantages over other similar materials in a number of unusual areas of utilization. At the same time, these characteristics impart a competitive disadvantage in more easily recognised areas of agricultural by-products. As such the first consideration in any scheme on rice husk utilization is complete familiarization with the usual properties of rice husk and its suitability in the manufacture of the proposed products.

c. Utilization Pattern

Conventional uses: Rice husk is used as fuel in rice mills where parboiling is practised and for domestic purposes in villages. It is used as a bedding material for animals, especially for poultry litter. It is used rather widely as a packing material to protect eggs, chinaware and other fragile commodities during handling and transportation. The black ash obtained after burning husk in used to lighten the soil. The husk-mixed bran available from huller mills is used as an animal feed. Sometimes when it is available in bulk and remains unutilized, it is piled outdoors. This gets scattered by wind and becomes a major source of environmental pollution. When rain soaked and decomposing, the piles can be set afire by spontaneous combustion. Additionally, husks have a low inertia which makes handling very difficult. The husks also cause excessive wear and tear on machinery because of the high silica content.

New uses: During the last two decades, a good deal of research work has been done in India on the potential uses of rice husk. This has resulted in the development of specific utilization concepts which have been exploited for meeting the following needs:

Husk-fired furnace: The energy requirements of a Rice Mill are of two types:

i) Parboiling-about 230,000 Kcal/tonne of energy is required for soaking, steaming and drying of paddy.

/ii)

ii) Milling operations-about 16,000 Kcal/tonne of energy is required for pre-cleaning, dehusking, winnowing, polishing, rice grading, and bran purifying with intermediat lifting.

The energy needs of the parboiling plant are so high that it is not economically feasible to run a commercial parboiling plant on fossil fuels. The present practice of cold water soaking and sun drying are no more liked by a rice miller.

The average calorific value of the rice husk is 3,000 Kcal/kg. Hence, a one tonne per hour rice mill producing about 200 kg husk/hr. is capable of generating 600,000 Kcal of heat energy per hour. If the mechanical conversion efficiency of 30% and a boiler efficiency of 45% are assumed, the heat is sufficient to undertake parboiling and milling operations. With these concerns in minds, research work has been initiated at the Institutes/Centres to develop a husk-fired furnace:

i) Punjab Agricultural University, Ludhiana;

ii) Indian Institute of Technology, Kharagpur;

iii) Central Fuel Research Institute, Dhanbad; and

iv) Paddy Processing Research Centre, Tiruvarur.

It has been found that these devices can extract up to 92% of potential energy of rice husk. Development of a self-supporting energy supply system in a rice mill complex will not only help to boost establishment of secondary industries like rice bran stabilization and oil extraction but also bring down the cost of rice milling.

Husk-fired domestic stove: In order to make a stove successful at the village level, the following considerations need to be kept in view:

i) The design of the stove should be simple so that it can be made by local blacksmiths.

ii) The stove should be light in weight and cheap.

iii) The filling of the husk should be so easy and continuous so that the stove can be kept burning without any interruption.

/iv)

iv) The amount of air should be variable so that the intensity of the flame can be changed.

v) The ash should be easily removeable.

For this purpose, research work has been initiated at the following institutes to develop a husk-fired domestic stove:

i) Punjab Agricultural University, Ludhiana.

ii) Indian Institute of Technology, Kharagpur.

Even though the efficiency of the husk stove is lower than those of stoves run on other fuels, the cost of fuel and the operating costs are relatively lower. This shows that the use of husk stove is quite economical as compared to other kinds of stoves.

Constructional Materials: During these days of shortages and spiralling prices, the cost of building materials has shot up exhorbitantly. Therefore, rice husk/ash - the silica-rich materials, have been used for the manufacture of construction materials.

Building bricks: The Regional Research Laboratory, Jorhat has developed a suitable substitute brick based on rice husk as raw material which can be used for small constructions. The main advantages of these bricks are: light weight, cheaper, reduced dead load, easy handling, better insulation, production not affected by seasonal changes. The bricks which have been tested as per ISI specification (IS:1725-1960) posseess requisite compressive strength. It has also been reported by the Paddy Processing Research Centre, Tiruvarur that white ash obtained from rice husk produced by slow burning under controlled conditions is a valuable raw material for brick manufacture.

Cement-like products: The Regional Research Laboratory, Jorhat, in collaboration with Annamalai University, Annamalainagar has developed a process for the manufacture of a cement-like product from rice husk ash for use in masonary morter, plastering foundation and mass concrete work. Similar work has also been initiated by the Cement Research Institute, Ballabhgarh. Unlike other cement plants, mini plants based on rice husk ash can be set up in different milling areas. In

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order to make this preposition feasible, R & D work needs to be undertaken on the following aspects :

i) Development of specification and testing procedure.

ii) The influence of particle size, shape, distribution, and the reactivity of the ash.

iii) Correlation of the nature of hydration products of rice husk ash cements with their strength and other performance characteristics.

iv) Investigation of the physical aspects of durability, volume changes and thermal properties of cementitious materials based on rice husk ash.

v) Activation of rice husk ash and the influence of the carbon content and other ash constituents on the reaction products.

vi) Durability of the reinforced concrete structures made with rice husk ash concrete.

Architectural Boards: The current practice is to use wood for making hardboard, insulation board and particle board. In the face of wood shortage in the country, it is imperative to find out suitable substitutes for wood products. All types of panel boards used for exterior or interior purposes in the form of wall boards, floors or ceiling can be made from agricultural residues using a resin to bind the materials together. The alternative would be to chemically transform some of the cellulose on the exterior of these hulls to a plastic which would bind the hulls to each other. Dr. R.C. Vasishth, Cor. Tech., Canada has prepared a feasibility report on the manufacture of composite boards from rice husk using batch-wise, labour-oriented process with particular reference to Indian conditions. This process uses phenol formaldehyde resin (8-19% of husk weight) that acts as a thermo-setting adhesive for the husks. The physical characteristics and properties of the boards have the potentiality of use as furniture, wall-panelling and as floor underlayerment.

/It is

It is contemplated to set up a demonstration unit jointly with the Haryana State Industrial Development Corporation. The Regional Research Laboratory, Jorhat has developed a binderless process for making particle boards from agro-industrial residues. The boards are cheap, water proof and eliminate the use of synthetic binder.

Chemicals and Special Products: Presence of high contents of silica, cellulose, lignin and pentosans has been fully exploited to manufacture a variety of the following products:

Sodium silicate: It exhibits strong adhesive properties similar to those of organic colloids like gums and resins; therefore, it finds a great variety of uses in chemical and other industries, viz., soap, petroleum, refrigeration, textile, cardboard, paper, glass, dyeing printing and building industries. At the Paddy Processing Research Centre, Tiruvarur, a process has been developed for the preparation of sodium silicate from the gray ash obtained from paddy husk-fired boilders. Even if only half a tonne of sodium silicate is manufactured, the earning per month has been calculated to at least Rs. 6000.00. This industry can be combined with a cottage scale soap industry, using high free fatty acid (FFA) rice bran as currently produced by the solvent extraction plants attached to rice milling industry.

Silica sol: It finds important applications in paper, textile and ceramic industries, polymers and resins, floor was compositions, molecular sieves, potassium silicate (electronic grade) and magnesium trisilicate. The Regional Research Laboratory, Jorhat has developed a process to manufacture silica solution based on rice husk ash. A 50 tonne per year silica sol 15% SiO_2 and 30% SiO_2 plants are estimated to cost about Rs. 360,000 and Rs. 490,000 respectively.

Activated carbon: It is used in large quantities in the refining of vegetable oils (both as a decolorize and deodorizer), rayon, molasses, fruit juices, glycerine and syrup. The Regional Research Laboratory, Hyderabad has developed a process to prepare vapour adsorbent activated carbon from rice husk (NRDC Process No. 234102). This carbon is of low ash content, having high adsorption capacity. It is particularly useful for pharmaceutical industries, the requirements of

/which

which are partly being met by imports. This process produces sodium silicate - an important chemical as a by-product.

Furfural: Rice husk with a pentosan content of 18.6% can be used for the manufacture of furfural - a solvent widely employed in the plastic, synthetic rubber and oil refining industries. It yields only 7.5% furfural. It should preferably be combined with raw materials such as corn cobs (11.0%), cotton seed hulls (12.5%) and oat hulls (13.5%) which are much more productive feedstocks for furfural. The manufacture of furfural requires a high capital intensive plant and therefore needs to be of very large size to be economically viable. Work has been initiated at the Indian Institute of Technology, Madras on the preparation of furfural from rice hull in a fixed bed reactor.

Insulating materials: Properties like density, heat value, fire retardance and thermal conductivity indicate rice husk to be a good insulating material. Rice hull can be made fire-proof by treatment with phosphoric acid and boric acid-borax mixture.

Sintered glass materials: When rice husk is burnt, the finely divided silica in it remains as a pseudomorph of the hull. Therefore, if rice hull is impregnated with a fluxing solution such as carbonate of sodium or calcium prior to burning, the silica structure in it is partially fluxed or converted to glass. The siliceous structure remaining after burning is sintered.

Fillers and extenders: Rice husk ground to desired fineness can be used as filler in plastic industry and various resin compounds employed in plywood glueing. However, the abrasiveness of the hulls and the ash pose a serious problem as it would affect the life of the plastic processing equipment. Problems connected with grinding costs and excessive wear have prevented the use of these materials in the past; recent situations warrant detailed investigations on testing its characteristics against the acceptable formulations with other fillers.

Agricultural Uses: Physical and chemical properties of rice husk have been used to satisfy various agricultural requirements.

/Mulching material

Mulching material: Husk has little fertilizer value except for adding some potassium to the soil. Husk can retain much moisture and tend to make the soil wet; so the beneficial effect of husk is found as a mulch rather than as a fertilizer. It improves soil temperature, water infiltration and soil structure. Rice husk as mulch increased significantly the yield of paddy in saline and alkali soils.

Filler in fertilizer mixture: Husk is used as a diluting component in commercial mixed fertilizers. The finely ground husk prevents caking of fertilizer salts and also tends to lighten the soil.

Disease resistance and phosphorus availability: Silicon accumulates in the epidermal cells, thus building up resistance to diseases. Silica also provides mechanical strength to plants. Moreover, because of the ability of silicate ions to displace phosphate ions fixed in the soil, silicon improves nutrient uptake particularly that of phosphorus. These properties confer beneficial effects on plant growth.

Animal feedstuff: Rice husk is not palatable to cattle; so this nutrient-poor, energy rich material is used under the acute scarcity of famine conditions in mixture with cereal straws. Untreated rice husk as animal feed is deletrious; the ammoniated product is free from such adverse effects.

This survey reveals that rice husk can offer a broad spectrum of utilization opportunities under different local situations. Nature of husk and the degree of fineness viz., whole husk, processed husk, ground husk, finely ground husk, high carbon and low carbon ash have a significant effect on the quality of the end product.

d. Problems in the Maximum and Better Utilization

Inadequacy of modernisation of rice milling: In India, there are about 88730 rice mills, out of which 71721 are hullers, 3770 shellers, 8213 huller-cum-sheller and 5026 modern/modernised rice mills. Huller mills give a mixture of ground husk, bran and finely ground rice particles which have little economic value except as animal feed or fuel.

/Modern

Modern mills, on the other hand, separate husk and bran. Therefore, the first essential pre-requisite in getting clean husk and bran is to modernise the huller mills. The National Productivity Council of India has initiated a techno-economic survey for modernisation of the rice milling industry in Kerala State. In Kerala where the husk is mostly used as fuel, the study is hoped to provide an answer to the possibility of modernisation and the availability of husk and bran separately for commercial utilization. Similar studies are urgently needed for other areas having concentration of rice mills.

The main limitation in achieving the objective of modernisation lies in the following advantages of the huller system:

i) The huller is cheap, easily erected, operated, repaired and maintained under rural conditions.

ii) It is available even in small sizes and can also operate intermittently to handle even small quantities of paddy.

The Paddy Processing Research Centre, Tiruvarur has shown that the defect of the huller is not in its function as a polisher but in its manner of operation for removing the husk (shelling) by abrasion. This processing defect can be overcome by using dehuskers which operate with rubber roller or rubber-lined discs.

Non-availability of commercial feasibility reports: No doubt a good deal of researchwork has been done in the country on the various aspects of rice husk utilization, but non-availability of project reports citing different local situations, has resulted in non-exploitation of its full scale potentialities by entrepreneurs.

e. Line of Action

From this brief description, it is evident that rice husk is a residue of great potential importance for the country. The following is the list of institution/laboratories working on the various end-uses of rice husk:

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1. Fuel and Power

   i) Punjab Agricultumal University Ludhiana.
   ii) Annamalai University, Annamalainagar.
   iii) Indian Institute of Technology, Kharagpur.
   iv) Fuel Research Institute, Dhanbad.
   v) Paddy Processing Research Centre, Tiruvarur.

2. Building Materials

   i) Central Building Research Institute, Roorkee.
   ii) Central Cement Research Institute, Ballabhgarh.
   iii) Annamalai University, Annamalainagar.
   iv) Regional Research Laboratory, Jorhat.
   v) Indian Institute of Technology, Kanpur.

3. Architectural Boards

   i) Regional Research Laboratory, Jammu.
   ii) Regional Research Laboratory, Jorhat.
   iii) Central Building Research Institute, Roorkee.

4. Industrial Chemicals and Special Products

   i) Regional Research Laboratory, Hyderabad.
   ii) Regional Research Laboratory, Jorhat.
   iii) Indian Institute of Technology, Madras.
   iv) Central Fuel Research Institute, Dhanbad.
   v) Paddy Processing Research Centre, Tiruvarur.

5. Agricultural Uses

   i) Soil Salinity Research Institute, Karnal.
   ii) ICAR All India Coordinated Research Scheme on Improvement of Soil Structure and Physical properties.

This broad spectrum of institutional infra-structure existing in the country on rice husk utilization, emphasises the need to set up an All India Coordinated Project, with the following objectives:

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i) To assess the availability and utilization pattern of rice husk region-wise with particular reference to its quality from different types of mills viz., modern/modernised, shellers, sheller-cum-hullers and hullers.

ii) Techno-economic feasibility of the processes envisaged, keeping in view the fluctuations in the cost price of the raw materials, transportation characteristics, processing costs and demand position of the end-products.

iii) To publish a Newsletter dealing with scientific, technical, socio-economic,environmental, administrative and legal aspects relating to rice husk utilization.

iv) To provide an effective forum for mutual exchange of information for scientists, technologists, rice-milling associations and other public and private agencies in the country.

v) To establish a documentation and date bank for collection and compilation of all technical and commercial information on availability and utilization of rice husk.

vi) To maintain liaison with its counterparts in ESCAP, UNIDO, FAO and other Regional and International agencies.

Formation of five Working Groups end-product wise viz., fuel and power, constructional materials, architectural boards, chemicals and special products and agricultural uses, can greetly help to fully exploit the utilization potential of rice husk to boost development programmes in the country.

2.2 Rice Bran

a. Availability: During the polishing of brown rice, about 5-7% polish is available in the form of bran. From 52.7 m. tonnes of clean rice, about 3.16 m. tonnes of bran, 0.57 m. tonnes of bran oil and 2.59 m. tonnes of deoiled bran can be obtained. Production of bran oil is about 80,000 tonnes, of which only a meagre quantity of 5,000 tonnes is of edible grade. This indicates that the potentialities of rice bran

/oil

oil industry in India are so vast that the rice crop will not be considered only a food crop but also an oilseed crop.

The economic extraction of oil from bran depends mainly on its quality. The oil content of the bran varies with the type of rice mill: bran from huller mills is 6-8%, bran from sheller mills is 12-15% and bran from modern rice mills is 15-20%. If the paddy is parboiled, the oil content of the bran increases considerably depending on the variety and the processing technique.

The main problems in the availability of rice bran are the following:

i) Large number of huller mills.
ii) Lack of centralized collection.

The bran available from hullers is mixed with finely ground rice particles which can find use only as an animal feed or fuel. Replacement of a huller by a dehusker having rubber rollers can overcome this defect. The economic benefits of this change have been shown by the Food Corproation of India at the Veeyar Rice Mill, Kuttalam in Thanjavur district (Tamil Nadu).

In many parts of the country, where small scale rice mills are located, the procurement of bran becomes the major impediment. Therefore, an organised collection either by a cooperative endeavour or by legislation is an important step to make solvent extraction economically viable.

b. <u>Composition and Characteristics</u>: Chemical analysis of rice bran shows wide variations (in per cent): moisture 8-12, protein 10-14, carbohydrates 38-44, oil 10-24, fibre 9-12, ash 9-12, pentosans 8-11 and B-vitamins 544 mg. Unlike other oils the crude rice bran oil contains wax, free fatty acids, gummy, colouring and odorous matters as well as organic impurities.

Rice bran oil is a high class edible oil containing unsaturated acids like oleic acid (41-45%) and linoleic acid (28-37%). It contains

/2-4%

2.4% tocopherol, 2-3% squalene and 2-3% oryzanol which accelerate human growth, facilitate blood circulation and stimulate hormonal secretions. Even though the linoleic acid content of rice bran oil is lower than that of sunflower oil, cotton seed oil, soybean oil, sesame oil and corn oil but its effect on lowering of cholestrol level is higher.

c. Problems in Refining Crude Rice Bran Oil

Crude rice bran oil is used mostly for non-edible purposes particularly as an ingredient in the manufacture of soaps, detergents, washing powder and paints; however, the easy availability of mutton and tallow as alternative substitutes have resulted in wide price fluctuations.

Edible-grade rice bran oil can be used like other vegetable cooking oils. The following are the main problems in refining rice bran oil:

High free fatty acid content: The enzyme lipase in freshly milled bran causes a very rapid hydrolysis of the oil, especially in a warm, humid climate. The development of FFA can be checked either by extracting the bran as soon as possible or stabilizing bran by inactivation of the fat-splitting enzymes. As the extraction units are to collect the bran in small quantities from a large number of rice mills scattered all over the country, there is always a time lag which results in the development of FFA which may vary from 20-40%. It is for this reason that most of the rice bran oil is not refined because of high costs involved. Work on stabilisation of rice bran is in progress at the following centres:

i) Central Food Technological Research Institute, Mysore.

ii) Annamalai University, Annamalainagar.

iii) Oil Technological Research Institute, Anantpur.

iv) Harcourt Butler Technological Institute, Kanpur.

v) Jadavpur University, Calcutta.

/Parboiled

Parboiled rice bran has a larger shelf life and a higher oil content also. Up to now difficulty was felt in solvent extraction of parboiled bran as good pellets were not formed; but this difficulty has been overcome by CFTRI, Mysore by using 1-2% molasses with parboiled bran. Use of these stabilizers has helped to keep the FFA below 4%; but economy study needs to be undertaken to select the economic size of the stabilizer unit for small/large-sized plants.

Large refining losses: The reason for high refining losses from high acidity bran is not completely understood; but the losses vary from 20-34% for the oil containing wax and from 14-19% for the dewaxed oils. Work carried out at the Oil Technological Research Institute, Anantpur has shown that incorporation of molasses prior to alkali refining can reduce these losses appreciably.

Handling of fines-materials of very small particle sizes: The fines occurring in rice bran tend to clog filters and make oils turbid. The fines also cause difficulties in settling out non-oily constituents. Increasing bran moisture to 16% and mild pre-cooking before extraction are reported to dimish the problem of fines. Use of silicate as a coagulating agent can further aid in clarification.

High sand, silica and hull content: These account for about 15-20% of bran. Their presence results in recovery of less oil and makes extraction uneconomical. Work done at OTRI, Anantpur has shown that air classification of sheller bran is effective in removing sand and silica because of wide differences in the bulk densities of rice bran (416 kg/m^3) and sand and silica (256 kg/m^3). Such separation is not possible in case of huller bran (density 402 kg/m^3) from powdered hulls (density 417 kg/m^3) because of their similar densities.

Presence of wax and unsaponifiable matter: Crude rice bran oil contains about 2-3% wax. This can be recovered by following a two-step extraction-first hexane extraction at temperatures below 10°C which removes most of the oil and very little wax; then a second hot extraction which removes was with a residual oil. It is normally dark brown in colour, has a characteristic odour and no sharp melting point. Work done at OTRI, Anantpur has shown that wax can be bleached by oxidation with

/ nitric acid.

nitric acid. Rice bran wax can be used as a partial substitute for some of the hard vegetable waxes which find numerous uses in polishes, food wraps and carbon papers.

Rice bran oil possesses high unsaponifiable matter varying from 4-7%. Work done at OTRI, Anantpur has shown that alkali refining and bleaching of oil result in reduction of unsaponifiable matter appreciably.

Colour and Odor: These can be removed by suitable processing techniques.

Thus, crude rice bran oil can be refined by neutralization, dewaxing, degumming, decolorisation, deodorization, and winterization. The vanaspati industry whose requirement is increasing every year, can help in developing edible grade oil industry by offering attractive incentives. Rice wax and soapstock obtained during the refining process can be put to valuable uses. Work is in progress at the following institutes on the refining of crude oil:

i) Harcourt Butler Technological Institute, Kanpur.

ii) Oil Technological Research Institute, Anantpur.

iii) Chemistry Department, Bombay University, Bombay.

iv) Central Food Technological Research Institute, Mysore.

The deoiled bran contains about 20-22% protein. It is a good foreign exchange earner. Deoiled bran can help to develop a balanced animal feed industry in the country. Recovery of high quality protein concentrate from defatted bran appears to be quite feasible. Rice bran protein is rich in lysine, an essential amino acid which is limited in cereal grains.

The Food Corporation of India and the Thanjavur Cooperative Marketing Federation have set up the joint rice bran oil Solvent Extraction Plant at Sambanarkoil in Thanjavur district. The plant is a continuous type with a capacity of 15 tonnes of rice bran/day.

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The project on Improving Quality of Rice Bran for Edible Oil Extraction has been undertaken by the Food Corporation of India with the financial grant the Department of Science and Technology. The objective of the project is to popularise stabilization of rice bran and improve its quality for producing edible-grade oil.

d. Line of Action

Maximum and better utilization of rice bran can help to meet the growing shortage of oils and fats in the country. The availability of 5.7 lakh tonnes of extra rice bran oil is equivalent to more than 14 lakh tonnes of oilseeds of which the country is critically short . With a view to develop the Solvent Extraction Industry based on rice bran, it is important to strengthen the following research centres:

i) Food Department Laboratory, New Delhi - Northern Region.
ii) Jadavpur University, Calcutta - Eastern Region.
iii) Central Food Technological Research Institute, Mysore - Southern Region.
iv) Oil Technological Research Institute, Anantpur - Central Region.

This regional strengthening of research centres would help in integrating the work done in various other laboratories situated in particular zones and for disseminating the know-how to the industry.

2.3 Rice Straw

a. Availability: Increased production of rice grain in the country also resulted in increased availability of rice straw. It increased from 38.48 m. tonnes in 1950-51 to 98.77 m. tonnes in 1977-78 (tables 1 and 2). In wheat growing areas of the country particularly Punjab, Haryana and Western Uttar Pradesh, wheat straw is used for feeding cattle and so, rice straw is available in plenty.

b. Composition and characteristics: It is a ligno-cellulosic material containing about 15-20% mineral matter. The ash is rich in silica with smaller amounts of alkaline salts. Water soluble content is fairly high. The bulk density of rice straw varies from 200-400 kg/m^3.

/c.

c. Utilization pattern: Traditionally, rice straw is used as cattle feed, manure, fuel, bedding, packing and thatching material in the villages. Rice straw is rich in potassium oxalate which causes severe alkalosis. Soaking of rice straw for 24 hours in 1% sodium hydroxide decreases the deletrious effect of potassium oxalate, increases calcium absorption and digestibility of carbohydrates.

Rice straw pulp resembles soft wood sulphite pulp in all characteristics except tear resistance but due to its slow drainage property and shorter fibre length, it can be used to produce high quality paper only in combination with some wood or rag pulp.

At present, a number of small units are manufacturing straw boards and corrugating medium. There exists the possibility that straw can be successful in the manufacture of bleached chemi-thermo and mechanical pulp for newsprint and cheap grade writing paper.

d. Line of Action: The main problem in the use of rice straw is its bulkinese and scattered nature which makes its collection, storage, handling and transportation difficult and costly. Therefore, it will be more worthwhile to lay stress on improving efficiency of rice straw for local purposes.

Conclusions

This brief survey indicates that rice husk, rice bran and rice straw offer a promising scope in residue management. Maximum and better utilization cannot only increase monetary return, improve ecology and local environmental conditions but also create many employment opportunities through development of secondary and tertiary industries.

/Table 1

III SUGARCANE (Sacchrum officinarum)

Sugarcane is an important cash crop of India with an area of about 3.22 m. hectares and production 181.63 m. tonnes. Sugar milling is the second largest industry in India with a network of 286 factories producing about 4.8 m. tonnes of sugar. Bagasse, molasses, pressmud are the main by-products available from this industry. Cane trash which comprises of leaves and tops is available in the form of crop residues. Sugar production and potential availability of residues during 1977-1978, statewise, is presented in table 3. There was an increase in sugarcane production during 1960-1961 (93%), 1970-1971 (137%) and 1977-1978 (218%) in comparison to 1950-1951 as the base year (table 4). The number of distilleries based on molasses has registered a steep rise. The processing operations based on sugarcane and its derived products are accompanied by generation of wastes in the form of affluents which pose a serious problem from the point of view of environmental pollution. The various aspects relating to the economic utilization of these residues and disposal of affluents are discussed and critically analysed.

3.1 Bagasse

a. Availability: Bagasse is the fibrous residue left after extraction of juice from sugarcane. The quantity of bagasse depends on the fibre content: 33-36% in Northern India and 26-30% in Southern India. On an average, bagasse constitutes about 1/3 of sugarcane crushed. From 67 m. tonnes of sugarcane crushed during 1977-1978, about 22 m. tonnes of wet or 11 m. tonnes of bone dry bagasse was available. The actual quantity of bagasse produced in sugar factories increased during 1960-1961 (179%), 1970-1971 (242%) and 1977-1978 (504%) in comparison to 1950-1951 as the base year.

b. Composition: The composition of bagasse depends on a number of factors viz., variety of sugarcane, maturity and method of harvesting, degree and efficiency of imbibition. The average composition of wet mill bagasse is as follows (in per cent): fibre 48.5, moisture 48.0

/Table 3

Table 3 Sugarcane production and potential, availability of residues during 1977-1978 (7000 tonnes)

State	Sugar-cane	Bagasse	Molasse	Pressmud	Cane-trash
Uttar Pradesh	80755.6	26918.5	3230.2	2422.7	8076
Maharashtra	23319.6	7773.2	932.8	699.6	2332
Tamil Nadu	17159.9	5720.0	686.4	514.8	1716
Andhra Pradesh	13267.8	4422.6	530.7	398.0	1327
Karnataka	11120.2	3706.7	444.8	333.6	1112
Haryana	8970.0	2990.0	358.8	269.1	897
Punjab	6520.0	2173.3	260.8	195.6	652
Bihar	4957.8	1652.6	198.3	148.7	496
Gujarat	3486.7	1162.2	139.5	104.6	349
Rajasthan	2854.4	951.5	114.2	85.6	285
Orissa	2600.0	866.7	104.0	78.0	260
Madhya Pradesh	2394.0	798.0	95.8	71.8	239
West Bengal	1812.4	604.1	72.5	54.4	181
Assam	1429.6	476.5	57.2	42.9	143
Other States / Union Territories *	1008.9	336.3	40.4	30.3	101
ALL INDIA	181627.9	60552.6	7265.1	5449.7	18116

* Kerala, Pandicherry , Nagaland, Tripura, Himachal Pradesh, Goa, Daman & Diu, Manipur, Jammu & Kashmir, Meghalaya, Mizoram, Andaman & Delhi

Table 4 Sugar production and potential availability of residues from 1950-1951 to 1977-1978

Year	Sugar-cane	Bagasse	Molasses	Press-mud	Cane-trash
1950-1951	57,051	23,073	2,769	2,077	6,922
1960-1961	110,001	36,848	4,422	3,316	11,054
1970-1971	135,024	42,123	5,055	3,791	12,637
1977-1978	181,628	60,553	7,266	5,450	18,166

Conversion ratios used: Bagasse - 1/3 sugarcane, Molasses - 4% sugarcane, Pressmud - 3% sugarcane and Cane trash - 10% sugarcane.

Source: Indian Sugar 29 (3) : 1979 and Indian Sugar Year Book, 1976-1977.

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sugar 3.0 and minor constituents 0.5. The average composition of bone dry bagasse is as follows (in per cent): cellulose 45, pentosans 28.0, lignin 20.0, ash 2.0 and sugar 5.0. Bagasse ash is rich in silica, potash and iron.

c. Utilization Pattern:

Fuel: The bagasse produced in India is almost entirely used as a fuel in the sugar factories for generating steam in the boilers to drive the prime movers as well as for boiling and concentrating sugar-cane juice. No doubt, the wet mill bagasse contains about 48% moisture but even then it is used after drying in special types of furnaces. The reason is that it is readily available without incurring any additional expenditure and also without depending on external sources of fuel. The average gross calorific value (GCV) of bagasse with 48% moisture is about 4,000 BTU/lb and that of furnace oil and coal are 18,000 BTU/lb and 11,000 BTU/lb respectively. One tonne of bagasse generates 2.5 tonnes of steam. Attempts have been made to compress bagasse into briquettes directly as a fuel substitute for charcoal, however, due to high potassium salts these could not replace coke in the firing of lime-kilns. At the National Sugar Institute, Kanpur, bagasse has been used for the production of methane. One tonne of bagasse generates about 200 cu. metres of combustible gas.

Pulp and Paper manufacture: The advantages of using bagasse as compared to bamboo in paper manufacture are the following :

i) Bagasse can be collected in large quantities easily from the sugar factories without involving heavy expenditure.

ii) Paper made with higher percentage of bagasse has good opacity and printing characteristics.

iii) Pulp produced from bagasse fibre has very good bursting strength and also requires less refining power.

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The disadvantages of bagasse as compared to bamboo are the following:

i) The cellulose content of wet bagasse is only about 20% as compared to 90-95% in soft woods and 60-70% in hard woods. Hence transport of bagasse from sugar factories would entail loading of large quantities of pith and associated moisture.

ii) Bagasse pulp is short fibred and therefore long-fibred pulp like bamboo pulp, waste paper, cotton linters or rags to the extent of about 25% has to be admixed for making good quality paper with good strength.

iii) Pith is highly absorbent and theefore improper removal of pith would mean high consumption of chemicals, drastic cooking and bleaching process. In addition, pith has a tendency to swell and become gelatinous which hinders filtration and washing of the pulp.

The problems of sugar factories in the matter of sparing bagasse by substituting it with alternate fuels are as follows:

i) The sugar factories are not sure of regular supply of alternate fuel at economic price. A 1000 tonne factory would require about 100 tonnes coal or 50 tonnes furnace oil per day.

ii) The conversion of the existing bagasse fired-boilers in the sugar factories for burning coal is very costly. The alteration would cost about 0.9 million for coal or about 0.5 million for furnace oil. Installation of new multi-fuel boilers with waste heat recovery units, pulverising equipment and conveyers would cost a considerable amount.

/The Development

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The Development Council for Paper, Pulp and Allied Industries constituted a sub-committee known as Bagasse Utilization Committee to examine the availability of bagasse for use in the manufacture of paper. The report of this Committee covered the following aspects:

i) The Committee estimates that out of 60 m. tonnes of sugar-cane, 20 m. tonnes with 50% moisture or 10 m. tonnes on bone dry basis can be made available provided alternate fuel is assured to the sugar mills.

ii) The Committee felt that very little surplus will be left for pulping if bagasse continues to be used as fuel by sugar mills.

iii) The Committee was of the opinion that the only possibility of saving bagasse for pulping is by installing coal/oil-fired boilers in the sugar mills.

iv) It was decided that in the face of shortage of fuel oil, only coal should be considered as alternate fuel to save bagasse.

v) The Committee was of the opinion that it is very difficult to burn pith in a boiler. Therefore, burning of the pith should not be considered while calculating the economy of using alternate fuel to save bagasse.

vi) The Committee concluded that it was not practicable to convert the existing boiler to coal fired; consequently a new coal fired boiler should be installed in the Sugar Mill by the Paper Mill on terms and conditions to be mutually settled.

vii) The Committee decided that for one tonne of coal having calorific values 10,500 BTU, the sugar mill will use 3.19 tonnes of bagasse with 50% moisture.

/Different

Different organizations as well as manufacturers of paper machinery have come to the conclusion that a small paper plant capable of producting 15 tonnes of white paper per day in 3 shifts is an economic unit. Mini paper plants attached to sugar factories have the following advantages:

i) The cost of transportation of bagasse is insignificant.

ii) Pith separated from bagasse can be burnt in the boilers.

iii) Steam and power requirements of mini paper plants can be met by the sugar factory itself through improvements in thermal efficiency by installing waste recovery units.

Thus, the working of integrated sugar and paper plants with an installed capacity of 5,000 tonnes per annum would be very successful. It may also help in the profitable utilization of agricultural and other residues like wheat straw, rice straw, jute stalks, cotton waste, cotton linters, gunnies, rags and waste paper.

Boards: Investigations have been carried out at the Forest Research Institute, Dehradum on the possibility of making straw and insulating boards from bagasse. Straw boards being crude and coarse can be manufactured from short-fibred materials like bagasse. The insulating boards prepared from this residue possessed satisfactory properties such as thermal conductivity, sound absorption coefficients, resistance to moisture and strength. Chemical treatment of boards rendered them immune, not only to termite and fungal attack but also made them reasonably fire-resistant.

Furfural: Bagasse contains about 21% pentosans which can yield 17% furfural on dry weight basis. The main factors influencing the choice of bagasse as raw material are its availability, delivery price, cost of conversion and the value of by-products obtained. The first furfural plant based on bagasse is being set up by Southern Agriculture Industries at Mundiyambakkam, a South Arcot Tamil Nadu village. The products to be manufactured include furfural, furfuryl alcohol and furane resins as well as potable liquor.

/Activated carbon

Activated carbon: The production of activated carbon from bagasse involves low temperature carbonization and simultaneous chemical activation. The carbon so obtained shows a kinetic behaviour similar to that of commercial carbon. It has higher capacity for colour removal compared to coconut shell and filter mud.

Animal feed: Bagasse can serve as an energy cattle feed. It is a rich source of carbohydrates but with little nutritive value. Recently, it has been found that ammoniation can increase the digestibility of the fibre. In this reaction, bagasse absorbs about 2% nitrogen. For adult cattle, bagasse can be impregnated with urea-molasses mixture, after fine chaffing.

Agricultural uses: Dehydrated bagasse is used for soil conditioning and as a compost. It has to be left to ferment and decompose for a fairly long period before working it in the soil.

d. Problems in handling and storage of bagasse

Fermentation: The low density and relative inflamability of bagasse make it a bulky and costly material to handle and transport. Fermentation sets in soon and the pith is attacked more quickly than the fibre.

Bagassesis: It is an industrial disease caused by inhaling bagasse dust by workers in factories where it is used in the production of paper, insulation boards and refractory bricks. It is an acute pulmonary illness, with cough, fever and breathlessness as the chief symptoms which appear after explosure to heavy concentration of bagasse dust. Epidermological survey and clinical observations indicated that neither allergy nor infection by bacteria or fungi played any part in the initiation of the disease, though they may contribute to the aggregation of the condition. Probably, the carbohydrate fraction might be responsible for initiating the symptoms.

/e.

e. Line of Action: From this description it is evident that only an integrated scheme can help in the effective exploitation of this valuable by-product. For this purpose, work needs to be taken up on priority basis on the following aspects:

i) Depithing of bagasse and the utilization of pith for the manufacture of particle boards, furfural, fuel briquettes and other uses.

ii) Utilization of whole bagasse and water extract from bagasse for the manufacture of furfural and other chemicals.

iii) Utilization of whole bagasse, depithed bagasse, residue left after water digestion of bagasse for the manufacture of pulp, paper and boards.

3.2 Molasses

a. Availability: Molasses is the residue left after the separation of all the crystallizable portion which can be economically obtained from it in the sugar factory. It constitutes about 4% of sugarcane. The actual quantity of molasses available from sugar factories increased from 0.446 m. tonnes in 1950-1951 to 2.691 m. tonnes in 1977-1978.

b. Composition: It is a viscous sweet liquid comprised of sugars (60%), water (20%), ash (18%), combined and free acids (6%), nitrogenous bodies (3%) and soluble gums (2%).

c. Utilization Pattern:

Industrial applications: About 70% of molasses produced in the country is being consumed by distilleries for the production of alcohol. About 3-5% molasses is used for tobacco curing and foundaries. It can, however, be used for the production of a number of important chemicals such as acetic acid, lactic acid, citric acid, butanol, acetone, glycerol, yeast, dextran, aconitic acid, itaconic acid and monosodium glutamate. The important end products obtained from molasses are the following:

/Alcohol:

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Alcohol: It is used as a solvent especially in paints, lacquers, varnishes, plastics, explosives, pharmaceuticals, drugs, and toilet preparations. Sale, distribution and prices of molasses are subject to the Molasses Control Order 1961 and subsequent amendments during 1971, 1975 and 1976. Under this order, three different grades of molasses and prices have been prescribed.

Lactic acid: It is used for a number of purposes in the food and pharmaceutical industry, preparation of vaccines, lyophilizing of blood plasma, as an acidulent, preservative and also in curing calcium deficiency. It is used in dentistry and jelly preparations, manufacture of plastics, synthetic rubber and paints. The technical grade lactic acid is widely used in the tanning industry.The National Sugar Institute, Kanpur has developed a process for the production of lactic acid from molasses by chemical means whereby a yield of 80-90% of sugar present in molasses could be obtained. The future research needs in this respect relate to carrying out pilot plant trials so as to streamline and establish the economics of this process.

Oxalic acid: It is widely used as a neutralizing and acidifying agent. It is also used as a whitener for leather and plant fibres. Sodium and iron salts of the acid are used as an antiflash agent in artillery and in the manufacture of blue print paper respectively.The National Sugar Institute, Kanpur has developed a process for the manufacture of oxalic acid from molasses; however, the pilot plant studies have to be carried out to find out the operational problems and the cost of production.

Monosodium glutamate: It is the sodium salt of glutamic acid. When added to food articles in small quantities, it intensifies flavour whereby taste and palatibility of the food products are considerably improved. It has also been recognized as a preservative because of its capacity to retard/arrest rotting of food articles. As such, it holds extensive demand by hotels, canning, soft drinks and food industries. It can be prepared from waste molasses by fermentation with *Micrococcus glutamicus*.

/Yeast:

Yeast: This industry has great potential in India. The manufacture of dry baker's yeast and other types of yeast (food and pharmaceutical yeast, distilleries and brewries' yeast) would not only help in import substitution but also play a vital role in the nutrition and health of the people. The India Yeast Co. Ltd., Calcutta is unable to meet the present demand. Processes for the manufacture of bakers' yeast have been developed by the following institutes/laboratories:

i) Central Food Technological Research Institute (CFTRI), Mysore.

ii) National Sugar Institute (NSI), Kanpur.

iii) Regional Research Laboratory, Jorhat.

The CFTRI process has been successfully commercialised by M/S Mohan Meakins Ltd. The finished products conforms to IS specification for bakers' Yeast (IS:1320-1958). The NSI process has been used by Dhampur Yeast Co., Dhampur, U.P. There is a strong need to develop a process for the manufacture of dry bakers' yeast which has several advantages over compressed yeast. The latter has to be transported packed in ice, preserved in the cold and used within a few days. Dry yeast does not have any of these limitations.

Enrichment of feeding stuffs: Molasses improves appearance, odour, texture and palatibility of the feeding rations. For young ruminants, it is used at 10% of the feed level. For poultry, levels below 5% have been recommended.

Agricultural value: Molasses is poor in nitrogen but rich in potash. Spray of a dilute solution of molasses boosts up yield particularly that of sugarcane. However, except in close vicinity to factories, it cannot be applied because of transportation problems.

d. Line of Action: Molasses is an important residue which finds a variety of applications both in the industrial and agricultural sectors. Diversification of use-pattern particularly in the yeast industry and manufacture of organic acids cannot only provide import substitution products but also lead to the establishment of secondary and tertiary industries. Preparation of a 'Status Report' on availability, present utilization pattern, socio-economic benefits, environmental

/pollution

pollution aspects and generation of employment opportunities can only help to assess the prospects and problems in the maximum and better utilization of molasses in the country.

3.3 Distillery Effluents/Spent Wash

a. Generation: The importance of ethanol as an alternate source of energy, in addition to its other conventional uses, has significantly increased during recent years. In India there are 127 distilleries with a total installed capacity of 732 million litre of ethanol per annum. For every litre of rectified spirit (ethanol) manufactured, about 15-20 litres of spent wash is produced which posses serious pollution problems, particularly due to its generation in substantial quantities with high pollution loads. It is characterised by low pH, 3.5-4.5 and high dissolved solids to the tune of 100,000 ppm and high BOD and COD loads of the order of 50,000 and 80,000 ppm respectively.

b. Treatment Methods for Disposal and By-product Recovery: The various distillery effluent treatments tried for reducing the pollution hazards are anaerobic lagooning, biological filters, growing of fodder yeast for cattle feed and anaerobic digestion for methane production; but all these methods suffer from the following common limitations:

i) Requirement of large land space for construction of a series of lagoons or ponds where land is limited.

ii) Requirement of large volume of water (7-10 folds) for dilution of the treated effluent before it could be discharged as irrigation water or in public sewerage.

iii) Because of the large amount of the effluent to be treated, these techniques become capital intensive.

The biological treatment of distillery waste using anaerobic and aerobic ponds and cultivation of acclimatized cultures in the ammonification process has been worked out at the National Sugar Institute, Kanpur. This process is comparatively simple and does not require complicated equipment. Ammonia produced helps to neutralize acidity.

/There is

There is no bad smell as in aerobic lagooning. The BOD is reduced from 50,000 ppm to 100 ppm and COD from 60,000 ppm to 3,000 ppm in a period of 10-12 days. The economically feasible solution to this problem lies in recycling the spent wash as wash water for repeated fermentations. This process has the following advantages:

i) Minimization of the pollutant size.

ii) Economy in the treatment of effluent.

iii) Saving of water and better waste management in industries.

iv) Saving of the acid used for adjusting the pH of the mash by diluting the molasses with acidic spent wash, hence economizing alcohol production.

In order to make this process an integral part of distilleries, there is a need to carry out the effect of the following on the rate of fermentation and recovery of alcohol:

i) Effect of salts, organic acids, caramel, furfural, aldehydes and fusels.

ii) Osmotic effect of different concentrations of non-fermentable sugar.

iii) Effect of recycling of different proportions of spent wash and rounds of recycling.

Full scale trials of recycling at a distillery and complete analysis of the recycled spent wash to eliminate its pollution load can only help to make appropriate recommendations.

Distillery effluents offer a promissing scope from resource utilization point of view. Neutralization with lime water, evaporation and enrichment can yield mixed fertilizers. Production of potash fertilizer from spent wash can help to provide an import substitution product. Absorption of spent wash in carrier solids such as paddy husk, groundnut shell, crushed wheat and rice grains can yield cattle and chicken feed. It also finds use in antibiotic production mainly streptomycin. Another alternative suggested relates to recovery of methane gas for the manufacture of chloromethane products; but many of these

/methods

methods require a large capital expenditure and hence are suitable for large distilleries only.

e. Line of Action: The air, water and soil pollution from the distillery wastes have become a serious problem; but at the same time, recent developments in biochemical engineering have opened up new vistas for recovery of by-products. The production of mixed fertilizers, cattle feed, recovery of methane and its use as a yeast growth supplement and the production of fungal amylase and streptomycin are some of the alternatives for development of new utilization patterns. In view of the serious magnitude of the problem and the prospective potential of recovery of economic products, it is highly important to identify the technological gaps so as to recommend specific treatment methodsdepending upon the nature of pollutants and size of the distillery.

3.4 Press mud

a. Availability: In the manufacture of sugar, the precipitated impurities contained in the juice, after removal by filteration form a cake called press cake. In the sulphitation factories, it amounts to about 3% and in the cargonation factories, about 7%.

b. Composition: Press mud primarily consists of a mixture of sugarcane fibre, sucrose, coagulated colloids including cane wax, albuminoids, inorganic salts and soil particles. It is a soft, spongy amorphous, brownish white material. Fresh samples contain 50% moisture chemical composition varies with the cane varieties soil-climatic conditions, the mill performance and the process adopted for clarification of cane juice.

c. Utilization Pattern

Agricultural values:The Bulk of pressmud from sulphitation factories is used as manure. It improves the physical properties of the soil particularly the pore size distribution, water retention capacity and soil aggregation, thus resulting in better root growth. Its application improves the nutrient uptake and cane quality of sugarcane. Pressmud from carbonation factories increases the yield of sugarcane in heavily leached, calcium-deficient soils.

/Wax:

Wax: The sulphitation pressmud contains sugarcane wax varying from 8-10% in various regions of India. On this basis, about 20,000 tonnes of wax can be recovered from this waste. The extraction of wax will definitely improve its manurial value. Moreover, the substitution of carnauba and vegetable waxes will help in saving a considerable amount of foreign exchange. Crude wax can be used directly in making carbon paper. Refined wax can be used for applying protective coatings on fruits for their preservation and preparation of waxed papers. For its use in paste polish industry, such as shoe polish, floor polish and car polish, the refined wax has to be modified in order to increase its solvent retentivity and gellying properties. Modified cane wax gives as high a gloss value as carnauba wax. A good deal of research work has been done at the National Sugar Institute, Kanpur on the various aspects of wax extraction, refining,deashing, defatting, bleaching and modification to suit different end-uses. The following two commercial plants are in operation: M/S Revalgaon Sugar Farm Ltd. Ravalgaon; M/S KCP Ltd. Vuyyuru. The cost of wax from pressmud depends on the following factors: wax content of mud, solvent used, type of plant, capacity of the unit and other local factors. Refining of crude wax has been patented by the National Chemical Laboratory, Poona. The estimated cost of a plant to treat 10 tonnes of filter mud yielding about 40 kg of refined wax is Rs. 15 lakhs only.

Building materials: The pressmud from carbonation sugar factories contains a high percentage of calcium carbonate and other materials like phosphorus, calcium silicate and magnesium. The organic matter present in pressmud has the potentiality to retain lots of water and as such, burning of pressmud requires more calories. Therefore, mostly it is used to fill in pits. The Central Building Research Institute, Roorkee has developed a method for converting carbonation pressmud into building lime according to ISI specifications. As compared to the cost of lime made from limestone, the cost of pressmud lime is only Rs.47.48 per tonne. Furthermore, utilization of waste mud for making building lime eliminates the cost of disposal.

/d.

d. Line of Action: Quick disposal of pressmud is very essential for the efficient working of sugar factories. Sometimes, a continuous and timely disposal of pressmud becomes a problem especially in factories having large crushing capacities. Hence, means for economic disposal need to be studied. It has proved useful for a number of crops but the main limiting factor is their transportation from factories to fields. An integrated approach aimed at removal of wax from sulphitation pressmud for use in place of carnauba wax and utilization of dewaxed residue for manurial purpose after enrichment, can help to improve the economic value of this waste material.

3.5 Sugar Factory Effluents

a. Generation: Sugar factory waste is one of the most complex and putrescible organic waste which creates serious problems of water pollution, sewere chokage and acute insanitary conditions in nature. The wastes arise mainly from mill house, filter cloth washings, boiling pans, floor washings, centrifigal units, leakage of juice and molasses from pipes, glands of pumps and spray pond overflow. The volume of the effluent of different sugar factories depends largely on the availability and consumption of water in a particular locality. Wastes from filter cloth washing is not large in volume as compared to the waste from other units but possesees high polluting gradients.

b. Composition: The final mixed wastes from sugar factories show wide variations in the chemical characteristics and possess organic pollutional substances principally sugar and carbohydrates. A survey of the sugar factories carried out in Uttar Pradesh showed BOD of the mixed waste varying from 805-1660 mg/lit. These values are much higher than the values suggested by ISI for safe disposal of the waste. ISI suggested that the waste containing BOD 30 mg/lit. can be discharged on inland surface and 500 mg/lit. for irrigational purposes. Similar is the position of total solids, suspended solids and grease in the mixed wastes. As the waste stagnates in the area of discharge for a few days, biological action starts with the production of obnoxious gases mainly hydrogen sulphide which imparts a black colour to the waste. If the

/mixed

IV MAIZE (*Zea mays*)

Next to wheat and rice, maize is an important food crop of India. It occupies an area of 5.70 m. hectares with a production potential of 5.95 m. tonnes. During the processing of maize for starch, germ oil and germ oilcake are obtained as by-products. Cobs and stalks are available as crop residues. Maize production and potential availability of residues, state-wise, during 1977-1978 is presented in table 5. There was an increase in maize production during 1960-1961 (130%), 1970-1971 (329%) and 1977-1978 (186%) in comparison to 1950-1951 as the base year (table 6).

4.1 Residues of Maize-based Starch Industry

The maize kernel is one of the most mysterious chemical entities of nature. It consists of hull, the insoluble non-starchy material; germ, the store-house of oil; gluten, the protein-rich portion and endosperm, the starch-rich component. The approximate chemical composition of a dry corn kernel is as follows (in per cent): carbohydrates 80, protein 10, oil 4.5, fibre 3.5 and minerals 2.0.

Wet milling plants are located at the following places:

i) Anil Starch and Chemicals Ltd., Ahmedabad.
ii) Maize Products (A division of Sayaji Mills Ltd.).
iii) Laxmi Starch Ltd., Hyderabad.
iv) Bharat Starch & Chemicals Ltd.,,Jagadhari.
v) Sukhjit Starch & Chemicals Ltd.,Phagwara.
vi) Rajaram & Bros.,Mandsur.
vii) Universal Starch Corn Allied Products, Dondaicha.

Besides starch and modified products, corn steep liquor, germ oil, germ oilcake, gluten, bran, zein and hydrol are obtained as by-products.

In India, there are 3 dry maize milling plants:

i) Food Corporation of India, Maize Milling Plant, Faridabad.
ii) Karnataka State Agro-Corn Products Ltd., Bangalore.
iii) South India Maize & Allied Industries Ltd., Madras.

/Table 5

Table 5 · Maize Production and Potential availability of Residues during 1977-1978 ('000 tonnes)

State	Maize Production	Maize germ	Maize germ oil	Maize germ oil cake	Maize cobs	Maize stalk
Uttar Pradesh	940.3	51.7	20.7	31.0	282.1	1880
Bihar	895.8	49.3	19.7	29.6	268.7	1792
Punjab	700.0	38.5	15.4	23.1	210.0	1400
Madhya Pradesh	553.8	30.5	12.2	18.3	166.1	1108
Rajasthan	515.8	28.4	11.4	17.0	154.7	1032
Karnataka	474.0	26.1	10.4	15.7	142.2	948
Himachal Pradesh	458.0	25.2	10.1	15.1	137.4	916
Andhra Pradesh	440.6	24.2	9.7	14.5	132.2	881
Jammu & Kashmir	378.3	20.8	8.3	12.5	113.5	756
Gujarat	121.8	6.7	2.7	4.0	36.5	244
Orissa	108.8	6.0	2.4	3.6	32.6	217
Maharashtra	107.2	5.9	2.4	3.5	32.1	214
Haryana	94.0	5.2	2.1	3.1	28.2	188
West Bengal	51.0	2.8	1.1	1.7	15.3	102
Other States / Union Territories	107.3	5.9	2.4	3.5	32.1	215
ALL INDIA	5946.7	327.2	131.0	196.2	1783.7	11893

Arunachal Pradesh, Tamil Nadu, Manipur, Assam, Meghlaya, Nagaland, Mizoram and Delhi

Table 6 Maize Production and availability of Residues from 1950-1951 to 1977-1978 ('000 tonnes)

Year	Maize Production	Maize germ	Maize germ oil	Maize germ oil cake	Maize cobs	Maize stalk
1950-1951	1729	95	21	74	519	3458
1960-1961	4080	224	123	101	1224	8160
1970-1971	7413	408	224	184	2224	14826
1977-1978	5947	327	131	196	1786	11893

Conversion ratios used: Germ - 5.5% maize grain, Germ oil - 2.2% maize grain, Maize cobs - 30% maize grain and Maize stalk - 200% maize grain.

Source: Estimates of Area and Production of Principal Crops in India 1970-1971 and 1977-1978. Directorate of Economics and Statistics, Ministry of Agriculture and Irrigation, Government of India, New Delhi.

During dry milling for flour and starch, germ, hull, grits and hominy are obtained as by-products.

a. Corn steep liquor:- Before degermination of maize grains, they are soaked in sulphurous acid for 40-60 hrs. so as to soften grains for grinding, to facilitate separation of protein granules that hold starch particles together, to remove solubles from germs, to stop the activity of micro-organisms and to bleach the starch. Therefore, the steep water from wet milling process contains the water-soluble constituents of maize-free amino-acids, proteins, carbohydrates, minerals and growth adjuncts. It is concentrated to about 50% solids and used as a nutrient for molds which produce penicillin and other antibiotics. It is an essential fortifying agent which affects a 50-100% increase in the yield of penicillin. Steep water concentrate may be mixed with gluten, bran and germ cake meal and marketed as animal feed.

b. Maize germ oil: The dried germs recovered in the wet milling process contain up to 50% of a semi-drying oil known as maize oil. This forms a subsidiary industry in the starch manufacture. Unrefined oil is used in soap industries.Demand for unsaturated edible oils which are high in linoleic acid content is increasing. Maize oil has big potentiality as cooking oil because of its anti-blood cholesterol reducing property. The 'Mazzola oil' is a refined corn oil put on market for this purpose. The free fatty acids of Indian crude corn oils appear to be rather high for refining purposes (8-12%). The contributing factors for high FFA in germs seem to be exposure of the separated wet germs for a length of time without proper drying and improper storage of partly dried germs. If care is taken for timely drying of germs, it may not be difficult to produce crude oil of 3% FFA in which case refining becomes easier and profitable. Earlier attempts at refining maize germ oil with about 10% free fatty acids were not encouraging as loose soap stock which could not be separated from neutral oil resulted in giving an appearance of an emulsion. Recently,the Oil Technological Research Institute, Anantpur has worked upon a centrifugal method using alkali lye for refining of Indian maize germ oil. Wax and odour are removed by cooling, filtration and steaming. Use of molasses as co-additive helps

/to reduce

to reduce the refining losses by 30-44% over the control experiments. Maize oil may be used with linseed oil as a paint material. Sulphonated maize oil finds applications in tanning and processing of leather.

c. Maize germ oilcake: It resembles coconut cake in organic constituents but is poor in mineral components. The requirements specified in the Indian Standard for maize germ oil cake are as follows (in per cent): moisture 10 max., ether extract 8 min., crude protein 18 min., crude fibre 10 max., and total ash 3 min. Animals fed with cake and roughage maintain good health and positive nutrient balance. Addition of berseem improves palatibility and digestibility of maize germ oilcake.

d. Maize gluten: In the wet milling process, it is seperated by centrifugation from the starch-gluten mixture. It contains about 50% protein. It is dried, reduced to a meal and used in feed concentrates. It is quite palatable and animals consuming gluten indicate positive balance with respect to nitrogen and minerals. In feeding value, maize gluten is inferior to groundnut cake but definitely superior to mustard cake. A mixture of gluten feed and bran is produced in two grades. ISI standards for these two grades are (in per cent): moisture (max.) 10, 10: crude protein (min.) 45, 23; crude fibre (min.) 45, 23; ether extract (min.) 4, 3; acid soluble ash (max.) 0.5, 0.5. These composite animal feeds are used mainly for feeding dairy cows.

e. Maize bran/husk: It consists largely of coarse and fine fibrous material. A good percentage of phosphorus in the bran occurs in the form of phytin. Trace elements reported to be present are Mn, Gu, Co and Fe. Maize bran is much inferior to wheat or rice bran as feed material. ISI Standards for coarse and fine brans are the following respectively (in per cent): moisture (max.) 11.11; crude protein (min.) 7.5, 14; crude fibre (max.) 12.5, 9.5; ether extract (min.) 2, 2.5 and total ash (max.) 1.5, 1.5.

f. Zein: It is recovered from maize gluten by destarching (using acid or enzyme hydrolysis). It is a yellowish powder which is fairly stable under storage for long periods. As a mixture with resins and plasticizers, zein is used in the production of moulded articles,

/varnishes

varnishes and adhesives. Zein protein is a rich source of glutmic acid which is used for the preparation of monosodium glutamate used as a sizing material for enhancing natural flavour of food.

g. Hydrol: It is the residual waste obtained in the production of glucose from corn. It is comparable to molasses obtained in the production of sucrose from sugarcane. The Harcourt Butler Technological Institute, Kanpus worked upon the utilization of hydrol for alcohol manufacture. This alcohol can be used in the manufacture of chemicals, hydrol is free from molassy flavour which persists in the distillate of fermented cane molasses and for this reason it promises to serve as a good base for products requiring alcohol of high purity. There is no sucrose. It contains only reducing sugars.

h. Maize grits: It is obtained during the dry milling of maize for the production of starch. It is fairly rich in protein content which makes it a desirable concentrate feed for farm livestock and poultry. It is quite palatable and no difficulty is experienced in inducing animals to consume it. Because it is deficient in mineral content, it should always be fed in combination with other mineral rich concentrates.

4.2 Maize Cobs (Pith)

Cobs comprise of about 25% chaff and 75% woody substance. These are used as a supplementary feed for cattle or as fuel (cal. value 17640 BTU/kg). Cobs are rich in pentosans and offer a potential source for the production of furfural - a chemical of great importance in the development of many industries like petroleum, nylon, vegetable oils, plastics, synthetic rubber and resins. In this regard, the Regional Research Laboratory, Jorhat has developed a process using a number of agro-industrial residues like maize cobs, bagasse, rice husk and saw dust as raw materials (NRDC Process No. 263112). The residue obtained after production of furfural from corn cobs can be used as a conditioner for mixed fertilizers. Certain refined forms of this residue show particular promise in foundry, moulding and in plastic compositions.

Corn cob is a poor conductor of heat and sound. Water, steam, frost and humidity have negligible effect on it. Corn cobs, cut into suitable

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transverse section of required thickness and pressed with glue between two veneers, make an excellent plywood. The finished product is lighter and cheaper than ordinary plywood. Increased durability can be achieved by treating the cobs with a light preservative.

Maize cellulose prepared by passing cobs between corrugated rolls designed to give a grinding-shearing action, is a highly efficient material. It has excellent cleaning properties and finds use in the metal finishing industry. It is used as a filler in the plastic industry.

Ground cobs, after screening are used for poultry. Addition of urea and molasses greatly improves their quality and palatibility. These find use as a mulch and soil conditioner. In the form of flour, cobs are used as a diluent and carrier for insecticides. Thick cobs of special maize varieties are used for making smoking pipes.

4.2 Maize Stalks

These find use either as animal feed or as manure. The softer stalks are fed to farm animals along with husk, skin and trimmings and the harder stalks are composted. Although maize stalks have been tested for making paper by many research institutions, transport and collection in any appreciable quantity are found to be costly. The paper making properties of this residue as a whole have also been shown to be relatively unsatisfactory for high quality paper. Maize stalks are less suitable than straw unless they are crushed, depithed and cleaned before pulping; otherwise the pulps are found to be brittle and dirty, possessing low physical strength properties and requiring a high chemical charge for pulping. The maize stalks are suitable for the manufacture of insulating boards and hard boards.

Conclusions

From this brief survey, it is evident that residues from maize and the maize based starch industry can provide a variety of end-products viz. cattle and poultry feed, oil, growth media, insulating boards and hard

/boards,

boards, furfural, resin and plasticizer. Modern processing methods not only help to divert the surpluses to some other channels of consumption but provide a variety of our needs e.g. if the germ alone could be separated from maize as in dry milling process, over 60,000 tonnes of refined edible oil can be extracted along with high protein germ oil cake for feed purposes. However, 3,000 tonnes of unrefined maize oil produced by wet millers constitutes only 5% of the total potential. This problem is something similar to the rice milling industry which is undergoing rapid modernization during recent times. A maize-based starch industry in India is hardly utilizing 55% of its installed capacity. As against 168,000 tonnes per annum, only 100,000 tonnes of starch and starch products are being produced. This calls for rethinking to promote the maize milling industry in the country.

V COCONUT (Cocos nucifera)

Coconut palm is rightly called the 'Kalpa Vriksha' (Heavenly tree) because it provides all the necessities of life. It supplies not only nutritious food and drink, housing and shelter but also raw material for a number of industries. India ranks third in the coconut producing countries of the world; Philippines and Indonesia occupying the first and second position respectively. During 1977-1978, 5733.6 million nuts were produced on an area of 1.08 m. hectares. Kerala is most advanced in coconut production, contributing about 59%, followed by Tamil Nadu 18% and Karnataka 14%. The bulk of the acreage under coconut is concentrated in the coastal and deltaic regions of South India.

Coconut oil is extensively used for edible and industrial purposes. It finds use in vanaspati and perfumery industries. Copra yields about 68% oil and 32% cake. Coconut husk, pith, shell, water, stem, leaves, buttons, spathe and root are the main residues available from coconut.

/During

During the last two decades, coconut production has tended to remain static, not only in India but on a global basis. Under such low production, and unfavourable competition facing coconut palm, there is an urgent need to improve the economic condition of the growers whose average holding is even less than one hectare through maximum and efficient utilization of residues available from coconut. Accumulation of these residues at one place not only creates 'disposal problem' but their biodegradation results in environmental pollution.

5.1 Coconut Husk

It constitutes about 50% of the weight of the nut. It is the raw material used in the coir industry which is earning considerable foreign exchange for the country. New uses of coconut husk include manufacture of architectural boards.

Particle boards made from chips of wood, bagasse and rice husk use large quantities of imported adhesives. It has been observed that coconut husk has self-binding properties. If it is chipped without its pith being separated, good quality particle boards can be made using these chips with little or no adhesives. The pith embedded in the coconut husk fibres contains reactive ingredients which during the process of making particle board undergo a chemical change and impart sufficient bond strength between the chips to form a strong board, thereby avoiding or minimising the requirement of resin adhesive. The Central Building Research Institute, Roorkee has developed a husk chipping machine with an average output of nearly 75 kg. per hr.

5.2 Coir dust/Coconut pith

a. Availability: It is the residue left over after extraction of fibre from the coconut husk. This light fluffy refuse constitute nearly 50-60% of the weight of the husk. It accumulates in abundance in the coir extraction centres in the coastal areas of Kerala. According to some rough calculations, about 160,000 tonnes of pith is annually available in the country. It piles up in plenty at the processing sites. So far it has defied any economic outlet. It constitutes a serious fire and health hazard.

/b.

b. Composition: It is a ligno-cellulosic material with a low nutrient content. It is too refractory to be composted. It absorbs moisture to the extent of 65%. It is saline in nature. The dust, on dry weight basis, contains about 10% long fibre, 20% short fibre and 70% pith.

c. Utilization Pattern

Agricultural uses: Coir dust is an excellent soil mulching material and has been used particularly in coconut nurseries and in citrus culture. It absorbs as much as eight times of its weight of water with which it parts fairly slowly. Coir dust mixed with sandy soil at 2% has been found to increase the water holding capacity of the latter by about 40%. Though it has been reported to be of great use as a rooting, seed germinating and soil conditioning medium, coir dust has but little manurial value. The dust from dry milled husk, however, contains about 0.5-1.0% potash. Coir-dust is sometimes used for reclaiming low-lying background areas.

Cement-coconut pith concrete: Coconut pith is a durable lightweight material having a high thermal insulation value. The Central Building Research Institute, Roorkee has developed a process to make cement-coconut pith concrete. As compared to conventional insulating materials ('thermocole', 'lime-concrete') this product is fairly cheap.

Expansion joint-filler: Cement concrete slabs in service show thermal movement of about 4 cm for every 100 metre length. To accomodate this movement, space is filled by a composition consisting of a filler, a sealing compound and in some cases, a water stop. The filler is known as 'expansion joint filler'. It is estimated that at present the country needs about a million square metres of this filler valued at about Rs. 1 crore. The Central Building Research Institute, Roorkee has developed a process for making expansion joint filler from coconut pith, cashewnut shell liquid, paraformaldehyde, rubber latex etc. It conforms to ISI No. 1838-1961.

/Architectural boards:

Architectural boards: It is claimed that durable, unlaminated boards of any thickness, capable of being sawed, mailed and glued, can be manufactured from a mixture of coir dust and coconut husk shorts.The possibility of partial substitution of phenol in phenol formaldehyde resins by coconut pith offer a promising scope.

Gaskets: The National Chemical Laboratory, Poona has developed a process to make gaskets from coir pith. These could be used in automobile oil engines and similar equipment as a substitute of rubberised coir sheets. The NCL process consists of mixing the coir pith with neoprene and other ingredients and vulcanising the mix in a press under pressure and temperature in suitable moulds. For a plant capable of producing 5.32 tonnes of finished product per annum based on 3 tonnes of coir pith, an investment of Rs. 1.33 lakhs has been estimated. The cost price of the product comes to Rs. 21,250/tonne.

5.3 Coconut Shell

a. Availability: In India, the estimated annual production of shell is about 1 m. tonnes, out of which about 50% can be collected from copra making centres particularly in the Central and Southern parts of Kerala, Karnataka, Tamil Nadu and Andhra Pradesh.

b. Composition: The moisture content of coconut shell varies widely according to maturity and storage. Mature air-dried shells contain mainly cellulose, lignin and pentosans. The ash from burnt shells contains a fair amount of potash, though less than that of husk.

c. Utilization Pattern

Domestic uses: Coconut shells are used for many domestic purposes e.g. hookah pipes, shell bottles and cups for collecting jaggery, rubber latex and butter milk.

Fuel: In South India, part of the shells are used as kitchen fuel and to a lesser extent in laundaries, smitheries, bakeries, lime kilns and brickyards. It is not favoured as a boiler fuel because of the corrosive nature of its vapours on fire bars and other metal parts.

/Fancy articles:

Fancy articles: Coconut shells are available in different sizes and shapes. It is hard, takes a high polish, can be carved, decorated with lacquer, inlaid with ivory, silver and other metals and generally used with ornamental effect. Lamps, goblets, flower vases, combs, laddles, bowls, buttons, cuff-links, ash-trays, trinkets, dishes, paper weights, tea-sets, musical instruments, spoons, sugar pots, and bangles are among the various fancy articles prepared from coconut shells; but such articles are not prepared on any large commercial scale.

Coconut shell charcoal: Charcoal is prepared by burning shells in a limited supply of air in suitable kilns. The yield of charcoal is about 30 per cent of the weight of the shell. It is extensively used in laundary, smithy and bakery. Well-powdered charcoal is used as a dentrifice It has a smaller percentage of ash than wood charcoal and therefore, if provided in better shape and form, can be utilized as a fuel for automobile gas generators.

Activated carbon: The carbon made from coconut charcoal is used mostly for the adsorption of toxic gases and vapours, purification of air, water, sugar rifining and the production of electrodes. In India, the Central Fuel Research Institute, Dhanbad and the Regional Research Laboratory, Hyderabad have developed processes for the manufacture of activated carbon from coconut shell. The main problems which hinder the development of this industry are the high cost of production and the competition from raw materials which are waste products from other sectors.

Coconut shell on destructive distillation produces various chemicals-acetic acids,wood spirit, phenol, cresote from the distilled liquor gas and shell charcoal. Under this process, the charcoal is likely to be of very good quality and can be used for making activated carbon. Being an integrated process, the economy of it is likely to permit reduction in cost in parity with other available varieties.

Conventionally, coconut shell is directly burnt and charcoal obtained, thus washing other by-products. Though coconut shell possesses definite advantages over ordinary wood for dry distillation, by reason of

/its

its composition, low hygroscopicity and the high yield of acetic acid and other thermal decomposition products derived therefrom; industrially it is not exploited. The main difficulty in the commercial utilization of coconut shell lies not so much in technical imperfections as in problems relating to collection and transport of raw material.

Coconut shell flour: It is important product used as a compound filler for synthetic resin glues and an extender for phenolic moulding powders. It gives a smooth and lustrous finish to moulded articles and also improves their resistance to moisture and heat. It is obtained by breaking shells into pieces and then grinding into fine particles of 100-500 mesh. In the wake of increasing demand for plastics as a group of materials in place of metals, the requirement of coconut shell flour is likely to be greatly extended in the years to come. The main problems in the development of this industry relate to the lack of suitable machinery. In the existing process, the resultant powder of 100 mesh is hardly to the extent of 60-70% whereas the requirement of plastic manufacturers is of 150-200 mesh; thus the present method is uneconomical. Another problem in the popularization relates to competition with other flours such as wood flour, walnut shell flour and coir pith ends. It is, therefore, considered necessary that overall existing and potential demand in plastic and plastic wood industries, both for internal and export, needs to be carried out along with the suitable type of machinery and techno-economic surveys.

5.4 Coconut Water

a. Availability: Large volumes of coconut water from the ripe nuts are run off as waste products of copra manufacture. The estimated quantity is about 0.5 m. tonnes. It is estimated that 100 nuts yield is 35 gallons of water.

b. Composition: The water of tender coconut is perhaps the purest of nutritious and wholesome beverages provided by nature. Analysis of coconut water indicates the following values: pH 4.8, water 95.5%, nitrogen 0.50%, phosphorus 0.56%, potassium 6.60%, reducing sugars 0.80%, sucrose 1.28%, total solids, 4.7 gm/100 ml and calorific value 17.4/100 g.

/c.

c. Utilization Pattern

Medicinal uses: Tender coconut water can be used intervenously for the following cases: gastro-enteritis, ambulatory type of hepatitis, bascillary dysentery, typhoid fever with diarrhoea and cases of dehyderation. There is hardly any danger of infection from external sources. Thus coconut water can be used for intervenous injection in rural areas where it is available cheaply at all times.

Growth media: Coconut water is an ideal substrate for luxuriant growth of yeast and bacteria which convert sugary substances into alcohol and vinegar; however, the design of the fermenter for vinegar fermentation is very much important to obtain better quality and pleasing flavour and aroma. Preventing coconut water from deterioration in quality and proper packing are the main problems in its large scale collection.

Rubber coagulant: Coconut water can be used in coagulation of latex but low concentration of acetic acid results in high packing cost.

Agricultural use: In view of the relatively high potash content, coconut water can be used for sprinkling in compost pits or even can be directly applied to coconut palms after neutralization.

5.5 Rotten Copra

Red coconut oil obtained from spoiled and brown coconuts possesses dark colour, rancid odour and high free fatty acid content even up to 30%. Therefore, it cannot find a market even for soap making. Treatment of the oil with hydrogen peroxide followed by bleaching with earth and activated carbon removes nearly 80% of the colour from the oil, and renders it suitable for soap-making and fat-splitting purposes. The oil required for edible usage can be obtained by processing with oxalic acid and alkali treatment. This work carried out at the oil Technological Research Institute, Anantpur has helped to utilize the rotton copra available in plenty in coastal districts (East and West Godavaris) of Andhra Pradesh.

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5.6 Coconut Stem, Leaves, Buttons, Spathe and Root

These are available in a scattered way on the plantation; therefore these are used mostly for domestic purposes. The leave are processed into brooms, mats and baskets. The timber is used for making village homes. The roots serve as herbal medicines.

Conclusions

In spite of great economic value of coconut, its processing has remained static for the last several centuries. The usual age-old method of drying coconut kernel into copra for subsequent pressing in rotaries and expellers to produce crude coconut oil and oil cake is very wastful, cumbersome, costly and liable to spoilage, rancidity and microbial infection. The ideal method of obtaining high quality oil and proteins for human consumption from coconuts would be direct processing of the wet meat out of fresh coconuts without drying the copra. This approach cannot only provide multipurpose products in place of crude oil and cake fit only for animal feed because of afflatoxin and other microbial contaminations. The process developed should be instant, efficient and economical in place of wasteful copra process. Moreover, from 100,000 coconut per day, about 20-25 tonnes of coconut shell, 100 tonnes of coconut husk and 50-60 tonnes of dry coir dust can be obtained. Destructive distillation of coconut shell and coir dust cannot only provide activated carbon but also a number of chemicals along with cooking gas. From coconut husk, about 10-12 tonnes of coconut fibre can be recovered. This integrated process would benefit the small coconut growers as well as generate employment potential in the area.

From this brief survey, it is evident that coconut residues serve many local purposes viz., fuel, manufacture of fancy articles, beverages and as a mulching material for sandy soil; but at the same time these offer promising scope for the manufacture of a wide variety of useful economic products viz., architectural boards, constructional materials, industrial products and vegetable oil. A switch over to the new alternative use patterns must satisfy the following pre-requisites:

/i)

i) Supply of a dependable substitute for the present local use.

ii) Efficient utilization of natural resources consistent with a clean environment.

iii) Labour-intensive, low capital technology, adapted to local skills and crafts.

This requires preparation of a feasibility report, keeping in view the following parameters:

i) Availability of raw materials in the light of local constraints-collection, transportation, storage, local usage and price structure.

ii) Appropriateness of the technology available.

iii) Demand survey of the end products.

Thus coconut production should not be regarded as a mere agricultural process but the harvest - a starting point for the manufacture of a variety of economic products. This calls for more research, enterprise, planning and organization.

VI TAPIOCA (Manihot esculents Crantz)

Tapioca is an important root crop of the tropics, particularly in Brazil, Indonesia, Nigeria and the Congo. India ranks fifth in the production of tapioca. This crop, long neglected by research workers, has now gained high priority both in national and international research programmes. The most important reason for this sudden upsurge of interest in tapioca is its significant role as a convertor of incident solar energy into energy-rich food and feed.

In India, tapioca is grown on an area of about 387,900 hectares with a total production of 6,492,700 tonnes. It is mainly concentrated in Kerala and Tamil Nadu. Intensive inter-varietal hybridization programmes have resulted in the evolution of many superior mutants viz., H-226, H-94 and H-165 with yields ranging from 235 q/ha-845 q/ha.

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/Tapioca

Tapioca is used mainly in the form of chips, flour, suji, starch, sago and macaroni. The pelletized product is preferred since it decreases the volume, is easier to transport and is uniform. It contains nearly four times the quantity of carbohydrates as that obtained from one hectare of rice.

The various types of residues available from tapioca are as under:

6.1 Peels, Pulp and Liquid Effluents from Starch and Sago Industries

Tapioca starch is manufactured from washed and peeled tubers by grinding with water in mechanically or hand-operated grinders. The slurry or starch milk is passed through strainers to eliminate fibrous impurities and is allowed to settle in tanks. Small quantities of sulphuric acid or alum is added to the settling tank to aid sedimentation; sulphur dioxide or chlorine may be used for bleaching. The starch which settles at the bottom is repeatedly washed, dried and sieved.

Tapioca starch is used in sizing and finishing textiles, laundering, paper making and manufacture of adhesives and cosmetics. It is used for edible purposes for making puddings, biscuits and confectionery. It is also employed for the manufacture of glucose, dextrin and alcohol. Modified starches have broadened the scope of usefulness of starch to meet specific requirements of a variety of food systems. Out of 6.49 m. tonnes of tapioca produced (60% moisture), as much as 3 m. tonnes are used for starch.

During the processing of tapioca for starch, peel, pulp and liquid effluents are available as residues. Peel constitutes about 11-14% (50% moisture). The total quantity of peel available from the starch industry is nearly 1.6 lakh tonnes. It has no use except as land fill. About 8-10% material is obtained in the form of pulpy fibrous waste during extraction, sieving and centrifigation. It is locally known as 'tippi'. It is estimated that about 2.4 lakh tonnes of tippi (10% moisture) is available from the starch industry in India. An analysis of a dried sample of tippi from a sago factory in Salem (Tamil Nadu) gave the following values (in per cent): moisture 11.2, starch 56.2, hemi-

/celluloses

celluloses 18.2, crude fibre 10.6, reducing sugars 1.2, crude protein 0.85, fat 0.3 and ash 1.5. The high percentage of starch is presumably due to the intact cells not ruptured in the rasping process. The Central Food Technological Research Institute, Mysore developed a process to recover starch from this fibrous waste. This starch can be used in the manufacture of sago and for other industrial purposes.

Fibrous waste finds use as a feed for cattle and poultry. It can replace ragi up to 50% in the feed of birds without having any adverse effect on their health and egg laying capacity. Rather there was about 12% increase in the number of eggs laid as a result of inclusion of tapioca spent pulp in the feed. Feeding trials carried out with growing and lactating animals revealed that the material can profitably replace maize/tapioca chips in the ration at 25% level and thus the cost of feed required for supporting body weight, milk yield and butter fat production can be considerably reduced.

During the manufacture of starch, a large quantity of water is used for root wash, extraction and sieving. The root wash water normally consists of cork cells, sand and clay particles. The separator water has high suspended organic matter and total solids; its high BOD and COD are the major cause of eutrophication in the nearby streams.

6.2 Demaged Tapioca Roots

Tapioca is the staple food of more than 200 million people in the tropics but very little is known as to why this crop cannot normally be kept in the fresh state for more than 2-5 days after harvest. Deterioration manifested in loss of quality and quantity results from pathological, physiological or mechanical damage. Reduction from mechanical damage is considered to be of paramount importance. These losses can be reduced by chemicals and refrigeration but such techniques are limited in application in the tropics by economic and organizational factors. Dehydrated tapioca flour could be used as a substitute for flour made from corn, wheat, rice and pulses in many food preparations. Dehydration process needs to be demonstrated to the growers at the centres of production.

/6.3

6.3 Tapioca Leaves

Tapioca leaf meal containing 17.58 mg HCN/100 g of material at an intake level of 0.5 to 0.8% of body weight of bullocks, 0.4% of lactating cows (30% of concentrate mixture) or 0.7% of the body weight of calves does not bring about any adverse effect on the physiological well-being of the animals, production performances or on growth response. Incorporation of tapioca leaf meal at 5% level in the diet of poultry layers enhanced the yellow colour of the egg-yolk. Leaf protein is rich in essential amino acids like leucine, valine, isoleucine and lysine. The stage of maturity and the types of soil influence HCN content. Plucking of leaves before harvest is deterimental to the yield of the tuber.

6.4 Tapioca Stem

On the basis of about 25 tonnes of tapioca stem per hectare, the total availability amounts to approximately 960,000 tonnes per annum in India. Nearly 20% of the stem from each crop of tapioca is used for replanting the next crop. In addition to use as a planting stock, the softer stems and leaves are used as fodder, fuel or manure.

In an attempt to assess the possibilities of using agricultural residues and some non-wood plant fibres for the manufacture of paper, paper board and nesprint in India, it has been observed by the Hindustan Paper Corporation, New Delhi that tapioca stem can be pulped by the soda and sulphite process and bleached without difficulty. Because of its short fibre length 0.5-0.8 mm, it is found to have low physical strength properties. As with other agricultural residues, collection transportation and storage are the serious problems.

The Research Centre of the West Coast Paper Mills Ltd. found tapioca stem pulp unsuitable for paper making because of the short fibre length, an appreciable pith content and low yield or pulp. The stem was found to contain 6.8% pith in the central core, 17.6% bark and the balance woody material.

/The Mysore

The Mysore Paper Mills Ltd. reported that tapioca stem pulp would not be suitable as 100% of the fibre furnish in paper making. Its pith content, high cooking chemical consumption and yield of about 28% were observed to be adverse factors affecting its use.

Conclusions

Residues from tapioca are mostly of biodegradable nature; thus their utilization is of utmost importance to minimise pollution. In view of the increasing demand for tapioca starch, the generation of residues is likely to increase. Therefore, research work needs to be intensified on the following aspects:

i) Selection of treatment methods to reduce pollutional load of effluents.

ii) Processing peels, pulp, leaves, damaged tubers into palatable and nutritious animal feed.

iii) Exploring possibility of using tapioca stem in mixture with other agricultural residues for pulp and paper manufacture.

/VII

VII OILPALM (*Elaeis guineensis* Jacq)

Oilpalm is by far the most productive oil tree in the world. The yield of oil is greater than any other annual or perennial oilseed crop. Oilpalm was introduced by the Indian Central Oilseeds Committee in the fiftees but its cultivation did not expand to any significant extent. It was only recently that Oilpalm India Ltd., a subsidiary of State-Owned Plantation Corporation of Kerala Ltd., has proposed to bring about 6,000 hectares under oilpalm cultivation. An area of about 1,450 hectares has already been brought under cultivation in Kerala, mainly at Anchal in Quilon district. Planted area in Andaman is nearly 200 hectares. Work in progress at three experimental stations viz., Elam Desam (Thoduphuzha near Alwaye, Kozha and Ollurkara (near Trichur) has shown encouraging results, thus opening up the prospects of large scale growing of oilpalm in several parts of the country. It has been estimated that a coverage of about 25,000 hectares can help to produce 50,000 tonnes of palmoil, 7,000 tonnes of kernel oil and 7,000 tonnes of meal.

The Oil Technological Research Institute, Anantpur carried out exploratory studies on the characteristics and composition of fruit and kernel of the oilpalms of Indian habitat with a view to screen problems that are likely to occur during processing of oilpalm fruits when large cultivation is established. Significant differences have been observed in the physical characteristics and composition of oilpalm fruit, palm oil, palm kernel oil and oilcakes obtained from Kerala and Andhra Pradesh. The main problems in improving the efficiency of palm oil relate to processing, refining and bleaching.

The following are the residues generated during the processing of oilpalm fruit for oil:

7.1 Empty Bunches

These constitute about 25-27% of fresh fruit bunches (FFB). The approximate composition on dry weight basis is (in per cent): lignin 20-25, pentosan 21-26, alpha cellulose 35-42 and ash 5. Each tonne of empty bunches contains equivalent of 6 kg of ammonium sulphate, 1 kg of

/rock

rock phosphate and 8 kg of potassium sulphate. These are disposed of by burning in a boiler or used as manure.The chemical characteristics of fruitless bunches are almost similar to those of hardwoods except for the higher pentosan content. The fibres are short and very slender but tough. Pulp studies indicate that these residues could be used to produce fine papers by sulphate process.

7.2 Palm Press Fibre

It comprises of pericarp fibre (11-15% on FFB) containing 30-40% moisture. It is rich in hollo-cellulose and lignin. It is obtained after the recovery of oil from the fleshy pericarp. It is a good raw material for pulp manufacture.

7.3 Nut Shell

It is obtained during the extraction of oil from the nuts. It contains 9-13% moisture and 87-91% non-fatty matter. The Main problems relate to drying and cracking of shells. It is used mostly as fuel or carved into ornamental objects. The shell charcoal possesses decolourising and gas adsorbent properties.

7.4 Palm Oil Waste

Palm oil mill effluent, a brownish colloidal suspension is produced from two processes in the factory viz., sterilization and clarification. The non-oily serum present in the palm fruit forms the effluent. Hot-water, added at various points in the processing mill dilutes the serum and adds to the volume of the effluent. It is estimated that the total waste generated from every tonne of fresh fruit bunches processed is about 680 kg. It has the following characteristics: pH 4.8, oil content 0.6%, BOD 18,000 ppm, COD 40,000 ppm, total solids 30,000 ppm, total suspended solids 10,000 ppm, ammoniacal N 30 ppm and nitrate N 9.3 ppm. The effluent discharged is mainly organic in nature, has a high BOD and suspended solids level which makes it a source of pollution.

This inorganic and organic load will result in depletion of dissolved oxygen content of the water-way, thus causing serious ecological

/disturbance

disturbance in the biological life. Resides this, excessive amounts of nitrogen in the wastes may lead to prolific growth of emergent and floating plants th at reduce the penetration of sunlight resulting in the reduction of available oxygen for marine and plant life. Bacteria present in the waste may render the river water impotable for human and/ or animal consumption.

The choice of an appropriate treatment process in a given situation depends on several factors: public health consideration, cost of ultimate disposal and economic viability of a particular factory, the depth and speed of the nearby stream. Amongst all the methods, the biological process consisting of a deep pond (anaerobic system) followed by a stabilisation pond (aerobic system) is considered to be feasible for treatment of palm oil effluents. The only constraint in using this process is the need for sufficient space for ponding. This method, however, is cheap, simple, locally constructible, rugged and requires little supervision.

Sludge in palm oil waste contains about 12% crude protein, 21% crude fat, 44% soluble carbohydrates and 12% crude fibre on a dry weight basis. This makes it a useful feed stuff for animals. Research work carried out by the Malaysian Agricultural Research and Development Institute (MARDI) has shwon that palm oil sludge and palm press fibre, alone and in combination, when dried down to 7% moisture content can be successfully used as a supplement feedstuff for sheep. Using press fibre as an absorbent, it is also possible to produce a valuable animal feed from palm oil mill mixed effluent. This by-product approach solves part of the effluent problem and could help to pay towards effluent treatment costs. This integrated approach is reported to eliminate the problem of excess fibre in the larger oil palm mills.

A lightly different method of utilizing palm oil sludge (termed the CENSOR approach) has been investigated upon by researchers at the University of Malaya. Tapioca and oil palm kernel (from the kernel oil extraction process) are used to provide an absorbent base for palm oil sludge having a moisture content of 90%. The resulting solid-wet mix is dried and pelleted to provide a high quality animal feed which shows promise as a substitute for maize in compounded animal feeds.

/Palm Oil

Palm oil sludge available in the tinning mills is presently a waste. The Regional Research Laboratory, Bhubaneswar has developed grinding/lapping compounds from this residue as raw material. These compounds are used for grinding of surfaces to desired fineness required for matching parts and valves, cutting paints before polishing metallic and non-metallic bodies. These can be marketed at a lower cost as compared to petroleum grease-based compounds.

Conclusions

Oil palm offers a promising scope for cultivation in this country because of the following advantages:

i) Yield of oil from oil palm is greater than any other oilseed crop. Even coconut gives about half the yield than that of the palm.

ii) It is a perfect edible oil. It is as good as groundnut oil and compares well with coconut oil.

iii) More than 35,000 tonnes of palm oil is imported every year at a cost of Rs. 3.75 crores. If available, more than one lakh tonne of oil can be used in the soap industry alone. An intensive oil palm plantation programme can help to save foreign exchange.

iv) Return on investment from oil palm is greater in comparison to other alternative crops in the area e.g. rubber, coconut and other palms.

v) Palm oil contains a high palmitic acid content. Therefore, it finds extensive use in tin plate process by Indian Steel and Tinplate Industries.

vi) An important side benefit resulting from installation of crushing machinery for processing palm fruit and kernels is the opening of new avenues for additional employment. This is particularly significant in view of the small holdings of a majority of cultivators.

/vii)

vii) Oil palm cultivation can also be adapted to many unused areas under a hot humid climate. This is borne out by large scale acreage being developed in Malaysia, Latin America and Africa.

Keeping in view the future prospects of the palm oil industry in this country, it is highly important to maximise use of residues consistent with a balanced ecological equilibrium. With this end in view, there is a need to set up a research centre to deal specifically with various aspects of oil palm processing and utilization of residues, some of which are given below:

i) To find out pulping characteristics of empty bunches and palm press fibre for use in paper manufacture.

ii) To develop a hydrocyclone for the separation of shells from the cracked nuts.

iii) To select an economic outlet for the disposal of nut shell-manufacture of fancy articles, activated carbon or for use as fuel.

iv) To choose a feasible treatment method for reduction of pollution in the nearby waterways.

v) To evaluate nutritional and economic potential of discharging this waste in the oil palm growing areas.

vi) To explore the possibility of using palm oil residues in conjunction with wastes from other sources for producing methane and single cell protein.

Maximum and efficient use of residues from the oil palm industry will not only help to solve disposal problems, minimise environmental pollution but also provide a variety of economic products in the form of animal feed, protein food, fertilizer, pulp and paper as well as industrial chemicals. These new uses will help to develop the secondary and tertiary industries - thus opening employment potentials in the local areas.

/VIII

VIII RUBBER (*Havea brasiliensis*)

The Rubber Plantation Industry occupies an important place in the economy of this country as it provides the principal raw material for the manufacture of a variety of products which are indispensable in modern life. India now ranks fifth among the national rubber producing countries in the world, the first four being Malaysia, Indonesia, Thailand and Sri Lanka. The value of the crop harvested annually amounts to over Rs. 110 crores.

According to 1976-1977, Rubber Board statistics, the area under rubber in India is 230,563 hectares. Kerala alone has 209,723 ha (91%) followed by Tamil Nadu 11,570 ha. (5%), Kernataka 7,763 ha (3.4%) and other states 1,505 ha (0.6%). In the North Eastern Zone of the country, which is the new home for rubber, Tripura is now on the top. Other adjoining States such as Assam, Nagaland, Manipur, Arunachal Pradesh and Mizoram have also taken up rubber plantations.

Most of the rubber is grown in small holdings. In all 136,532 units cover an area of 163,084 ha and 595 estates have 67,479 ha area under rubber. The small holdings at present account for 63% of the total production. Thus, by virtue of their number, coverage of area and contribution to production, the small holdings have come to occupy an important position in the industry.

Rubber plantations have recorded spectacular progress during the last three decades. From 65,376 ha in 1948-1949, the area has jumped to 230,563 ha in 1976-1977, an increase of 253%. Similarly, the production has increased from 15,394 tonnes in 1948-1949 to 149,632 tonnes in 1976-1977, an increase of 872%. From the rubber plantations and rubber industry, the following by-products/wastes are available:

8.1 Rubber Seed

a. Availability: Potentially 100,000 tonnes of rubber seeds are available from rubber plantations but only 23,000 tonnes are actually collected/processed. It has been estimated that on the basis of 50

/seeds

seeds per tree, a hectare can provide about 17,500 seeds at a stand of 350 trees. This is equal to 80 kg on the basis of 220 seeds/kg. This may however, vary according to seasonal changes and pod incidence.

b. Composition: The rubber seeds resemble castor seeds in appearance; they are larger and heavier (2-4 g). These consist of approximately 40% shell and 60% kernel. The oil content of the kernel corresponds to about 25% of the seeds on moisture free basis. The oil obtained from the kernel is clear, of light yellow colour and has an odour somewhat resembling to that of linseed oil. The husk contains a solid fat which has a high saponification number and low iodine value but the amount of fat in the husk is very small. Rubber seed oil consists of principally the glycerides of the unsaturated acids like oleic acid, linoleic acid and linolenic acid along with a small quantity of saturated acids.

The kernels of rubber seeds contain a powerful active lipolytic enzyme and a cynogenetic glycoside which decomposes lateron, either as a result of enzyme action or as a result of too much acidity, thus yielding hydrocyanic acid in the meal obtained from the kernel. The oil is almost free from the glycosides and hydrogen cyanides. The cake has a high protein content and carbohydrates.

c. Utilization Pattern: During 1965, the extraction of oil from mubber seed was not widespread. The increase in the prices of non-edible oils and the restrictions imposed on the import of goods during the seventees gave a good fillip to this industry and a number of organizations showed interest in the commercial trading of rubber seed oil. This stimulus prompted the Rubber Board to conduct an exploratory survey is Tamil Nadu and Kerala on the quantity of rubber seed produced, the method of processing rubber seed kernel, the trend in the consumption of rubber seed oil and cake and other connected details of the industry.

Influence of local factors

Processing of rubber seed for oil extraction: The millers of Tamil Nadu have the following advantages in comparison to those in Kerala:

/i)

i) They have been processing groundnut but this crop arrives late at the mills after December whereas the rubber seed is available between July and September. As such it is convenient for groundnut oil millers to process rubber seeds during the slack months.

ii) The climatic condition of Tamil Nadu is conducive for drying rubber seeds prior to crushing. During July to September it rains heavily in the West Coast of India while there is hardly any rain in the inland districts of Tamil Nadu. This enables the millers to dry the rubber seeds in the sun.

iii) Further, vacant spaces are available to dry rubber seeds in the compounds of rice mills of Tamil Nadu during that period. Some of them rent out that facility to oil millers.

iv) Labour for shelling and handling of seeds is more cheap and plentiful in Tamil Nadu than in Kerala.

In Tamil Nadu there are 75 units which processed 11,670 m. tonnes of dry kernel whereas in Kerala, only 400 m. tonnes was processed in 22 units during 1976-1977.

Consumption of rubber seed oil: During 1976-1977, about 4200 m. tonnes of rubber oil was available, out of which 1820 m.tonnes was consumed by 89 soap industry units in Tamil Nadu located mainly at Madurai, Coimbatore and Tiruppur. In Kerala only 50 m. tonnes was used and the washing soap manufactured out of rubber seed oil was of inferior quality. The saline water found in the coastal parts of Kerala also deters its use. Moreover, the soap manufacturers of Kerala get considerable quantity of mutton tallow at competitive price. These factors have reduced the consumption of rubber seed oil in Kerala.

New uses of rubber seed oil and cake: Rubber seed oil is used mostly for soap manufacture but reeently work has been initiated on the following new products/uses:

/Factice:

Factice: It is recognised as a valuable processing aid by rubber technologists. This material possesses certain intrinsic properties which make it indispensable in mixes during milling, calendering, extrusion and injection moulding. A wide range of vegetable oils are used for factice preparation. Linseed, rape seed, cotton seed, soyabean and fish oils are some of the widely used glyceride oil oils. Investigations undertaken at the Rubber Research Institute of India, Kottayam have revealed the possibilities of utilization of rubber seedoil for factice manufacture.

Expoxydised products: The epoxidised oils and esters of unsaturated fatty acids are widely used in polyvinyl chloride and its co-polymers in conjunction with other substances to impart a spectrum of properies e.g. heat and light stability, superior ageing and low temperature flexibility. Epoxidised products also find use in the formulation of anti-corrosive coatings, adhesives and alkyd resin coatings. Work has been done on the epoxidation of groundnut, cotton seed, safflower seed, tobacco seed, sesame, niger, rice bran and ajjowan seed. The investigations carried out at the Rubber Research Institute of India, Kottayam has indicated the possibility of epoxidation of crude rubber seed to obtain products with satisfactory oxirane content.

Animal feed: Formerly rubber seed cake was used only as manure but recently the investigations carried out by the Kerala Agricultural University, Trivandrum have shown that rubber seed cake can be used as an ingredient of livestock feed. Therefore, the Poultry Feed Manufacturing Company, Malampuzha (a Company owned by the Government of Kerala) is using this cake up to 10% of the total weight of the feed. During 1976-1977, about 8,000 m. tonnes of rubber seed cake was produced in the country.

On the basis of the estimated production of rubber seed oil and cake, the industry has added nearly Rs. 27 million to the national income during 1976-1977.

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d. Problems in Maximum and Efficient Utilization

Collection of seeds from estates is a difficult process. In order to prevent lipase activity, the collected seeds need to be heated immediately. Cooking of rubber seeds with steam makes the kernels soft and resilient like rubber and because of this condition of kernels, their crushing in the expeller chamber becomes a problem. The oil obtained is high in free fatty acid and hence not amenable to alkali refining. Kernels have a tendency to brown with age and the extractable oil content diminishes with increasing brownness of the kernel. The shells and kernels are almost of equal bulk density. This hampers an effective separation of shells from kernels. The decortication of the seed takes place completely but the separation of shells from kernels requires recycling. For one tonne of rubber seed, it takes 8 hrs. for complete decortication and separation of shells from kernels. Therefore, for economic production of oil from the seeds, methods of collection, preservation, extraction and refining need to be improved upon. If proper methods are developed for removing hydrocynic acid from the cake, it may prove to be a good cattle feed.

8.2 Rubber Wood

a. Availability: Assuming that the average stand per hectare is 200 trees and about 5 cu. ft. stem wood is available from each tree, the total availability of rubber wood per hectare works out to be 1,000 cu. ft. On this basis, nearly 4 m. cu.ft. would be available from the natural rubber plantation industry in the country. Output of wood per tree depends on the planting material, age, soil conditions and the number of trees per hectare. It is largely available in Kottayam, Quilon, Ernakulam, Malapuram, Kozhikode and Cannanore districts of Kerala and Kanyakumari district of Tamil Nadu.

b. Nature and Characteristics: It is rich in cellulose and lignin. On the basis of its physical and strength properties, it is classified as light hardwood. It is moderately easy to saw, plane, bore and turn. It is relatively fast drying compared to other hardwoods. Unlike most tropical hardwoods, rubber wood is readily attacked by insects and

/fungi.

fungi. Rubber wood rich in silica is resistant to the attack of borers. The species high in leachable extracts may be a good source of tannins, resin or dye; those having high cellulose content can be expected to yield more chemical pulp and paper than species low in cellulose; species high pentosans may yield a semi-chemical pulp of high strength.

c. Utilization Pattern

Conventional uses: Rubber wood is used mainly for domestic cooking and in brick kilns. It is purchased by packing case manufacturers particularly for tea chests. In view of its strength and machining properties, it finds use in making furniture, lamp stands and souvenirs.

New uses: Rubber wood is readily available and at a comparatively low cost; therefore, it can be advantageously employed for making particle and fibre boards. Attempts have been made by the Forest Research Institute, Dehradun to utilize rubber wood for paper manufacture and by the Gwalior Rayons for the manufacture of rayon fibres. In practice, the wood pulp is suitable for making lower quality paper products - paper bags and cardboards due to contamination by residual rubber. If rubber is removed from wood before it is pulped, other types of paper such as writing and printing papers could also be produced. When this comes about, rubber wood would be a major source of raw material for the local pulp and paper industry.

d. Problems

The main problems in the utilization of rubber wood are the presence of latex in the wood and susceptibility of wood for fungal and insect attack.

8.3 Rubber Factory Effluents

Rubber latex contains about 30 per cent of non-rubber constituents. During processing of rubber, these are washed away into rubber serum. The effluent generation of an average 20 tpd factory is estimated at

/410 kl.

410 kl. The general characteristics of the effluent are: pH 4.86, total suspended solids 340 ppm. total solids 1880 ppm, volatile solids 1440 ppm, COD 2180 ppm, BOD 1040 ppm, ammoniacal N 85 ppm and total N 150 ppm. The following are the chemicals used during the processing of block rubber:

i) Ammonia as a preservative for the latex during transportation.

ii) Acetic/Formic acids for coagulation.

iii) Sodium-bi-sulphite, for preventing surface darkening of coagulum.

At present, the following 8 factories are producing block rubber in India:

i) Palai Marketing Co-operative Society Ltd., Palai, Kerala.

ii) Heavea Crumb Pvt. Ltd., Poovarany, Palai, Kerala.

iii) Rubber O Dynat (India) Pvt. Ltd., Kalamassery, Cochin, Kerala.

iv) Plantation Corporation of Kerala Ltd., Kottayam, Kerala.

v) Travancore Rubber & Tea Co., Ltd., Trivandrum, Kerala.

vi) Mambad Rubber Manufacturing Co. Ltd., Calvetty, Cochin, Kerala.

vii) Malankara Rubber & Produce Co. Ltd., Kodimatha, Kottayam, Kerala.

viii) Pilot Crumk Rubber Factory, RRII, Kottayam, Kerala.

Several methods have been suggested to economically treat these effluents which vary in quality and composition according to the process employed, quality control and supervision. Some factories give partial treatment (ponding, pitting or filtering) before discharge of the effluents to recover suspended latex.

Skim serum, an unwanted by-product of latex concentrate production, is normally disposed of in the nearest stream. The unusual

/chemical

chemical composition (pH 4.1, total solids 42,550 ppm, volatile solids 36,410 ppm, suspended solids 2850 ppm, COD 32,690 ppm and BOD 13,670 ppm) tends to aggravate stream pollution. It offers great potential for use as a fertilizer. large dilution of skim serum will increase the distribution cost. Transportation of serum over larger distances makes this proposition uneconomical.

The major attention is being devoted to the solution of environmental pollution problem created by rubber processing industry. The multi-pronged efforts include micobial degradation of wastes, their use as a medium for growing of yeasts, algae and fungi, as a seedling material for latex coagulation, as a fertilizer, and as a source of chemicals. The yeasts grow well on the effluents. Experiments on growing algae along with fish in treated effluents have given satisfactory results. The skim serum has been used as a soil stabilizer for maize, soyabean and groundnut increasing the crop yields by 75, 89 and 27 per cent respectively. The isolation of querbrachitol, various enzymes, proteins (as an aninal feed) and inorganic salts are other possibilities which are being investigated.

Conclusions

Industries based on rubber seed oil and rubber wood offer a great potential to provide employment to small holders and generate benefits from the socio-economic point of view. Further work needs to be intensified on the following aspects:

i) Improvements in processing of rubber seed oil and manufacture of factice and epoxidised products.

ii) Improvements in removal of hydrocynic acid from rubber seed cake for wider use as animal feed.

iii) Improvements in the quality of rubber wood for use in furniture, pulp, paper and board industry.

iv) Treatment methods to minimise pollution, load in effluents and recover economic products.

/CONCLUDING REMARKS

CONCLUDING REMARKS

The present paper gives a broad outline of the various types of residues available from agriculture and agro-industries, their alternative uses and the processes developed by different institutes/ laboratories for their utilization. An analysis of the problem would reveal that there are many local, economic, social technological and legal factors which limit their maximum and efficient utilization. Besides these constraints, agricultural residues themselves present several specific problems such as:

i) Scattered nature causing collection problems.

ii) Bulky nature causing transportation problems.

iii) Perishable nature leading to environmental pollution.

iv) Unusual chemical composition necessitating pre-treatment.

v) Conventional uses resulting in limited availability for commercial utilization, and

vi) Alternative use pattern resulting in choice problems.

There are two main objectives of residue utilization:

i) Minimization of environmental pollution resulting from biodegradation of organic compounds.

ii) Utilization of residues as a source of useful economic products.

Keeping in view the characteristic features of the following types of agricultural residues, a differential approach will have to be adopted to meet the above objectives:

i) Crop residues.

ii) Agro-industrial by-products.

iii) Factory effluents.

Crop residues and scattered types of waste present collection and transportation problems; therefore major stress will have to be laid on

/enhancing

enhancing their utilization locally for such purposes as

i) Improving their fuel efficiency by devising better stoves, hearths and furnaces.

ii) Improving nutritional efficiency and palatability by pre-treatment or by making proper admixtures.

iii) Improving the quality of organic manures by minimizing leaching and volatilization losses and proper enrichment.

iv) Improving the strength of organic materials used for building purposes through proper processing.

Any plan envisaged for commercial utilization of residues must satisfy the local requirements, either by providing substitutes or through the adoption of an integrated approach.

Agro-industrial by-products are available at the processing sites in sufficient quantities. They offer a promising scope for commercial utilization, but to decide upon the best possible use, the following factors need to be taken into account:

i) Quantity of residues available, area-wise, in the context of their conventional uses.

ii) Physical and chemical characteristics of the residues.

iii) Appropriateness of the technology available in relation to the local conditions.

iv) Market value of the economic products vis-a-vis that of their competitive substitutes, and export potential.

v) Employment potential.

vi) Environmental aspects.

vii) Socio-economic benefits.

Factory effluents originate in the form of waste water and pose a serious threat to all biological life. Choice of treatment methods for disposal/utilization is governed by the following factors:

/i)

i) Nature and composition of the effluents in terms of pH, BOD, COD, total, suspended and volatile solids and the presence of specific chemicals.

ii) Depth, speed and extent of the nearby waterflow.

iii) Possibility of recycling water in the factory.

iv) Recovery of economic products.

v) Climatic factors.

vi) Nature and applicability of legal standards, and

vii) Financial soundness of the concerned factory.

The major gaps responsible for non/under-utilization of agricultural and agro-industrial residues are the following:

i) Lack of suitable linkages between agro-industry and R & D institutions.

ii) Lack of awareness on environmental hazards resulting from indifferent attitude to residue utilization.

iii) Lack of appropriate and integrated technology commensurate with local conditions and chemical compositions of residues.

iv) Lack of suitable training facilities/information media on residue utilization.

v) Lack of information on resources availability position, residue-wise/area-wise, in the light of their local uses, bulky and perishable nature and transportation difficulties.

vi) Lack of market surveys on the demand position of end-products vis-a-vis alternative substitutes, and

vii) Absence of a National Co-ordiantion Agency on Residue Utilization-Management of Agricultural and Agro-industrial Residues.

From the state of art, it is evident that a large number of agencies are engaged in research and development work relating to the utilization of agricultural residues in the country. As such, there

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appears to be no need for the creation of a special infrastructure for the purpose. What is needed at the moment is only an inter-institutional and inter-disciplinary forum for the exchange of information and for generating cooperation in this vital field. It is essential to have a National Centre on Residue Utilization charged with the responsibility of preparing a comprehensive plan which may not only be technologically sound but also socially and economically feasible and environmentally compatible.

The activities of this National Centre would help to cater to the needs of the following:

i) National Planners: A critical study of the various factors influencing selection of viable projects may help Resource Utilization Sections of various Departments/Ministries/Planning Commission to boost up feasible projects. This information will be useful for a number of agencies e.g. Department of Science and Technology, Indian Council of Agricultural Research, Council of Scientific and Industrial Research, Ministry of Agriculture and Irrigation, Directorate General of Technical Development, Khadi and Village Industries Commission, State Departments of Agriculture, Animal Husbandry, Forestry, Fisheries, Horticulture and Industries as well as other public and private agencies. By acting as a data bank for each class of residue, it may help in investment decisions for funding R & D projects.

ii) Environmental Pollution Control Agencies: There is an intimate relationship between residue utilization and environmental safety. Bio-degradation of perishable residues immediately sets in, resulting in pollution of air, water and soil. Therefore, the projects envisaged should not only be technologically sound but also compatible with environmental standards.

iii) Agro-industrial Associations: Agro-industries are not only the producers of residues but also the users of technology.

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The National Centre will help to strengthen linkages between the agro-industrial associations and the R & D institutions - an aspect which needs due recognition and emphasis for promoting residue utilization programmes in the country.

iv) Research Scientists and Technologists: Compilation of a Directory of Outlines of National Priorities based on local resource opporunities and employment potential will help the research institutions to select viable projects and thus help in efficient utilization of indigenous resources.

v) Educational Institutions: Preparation of a Model Course Curriculum on Residue Utilization will aid the Engineering, Industrial, Agricultural and Management Faculties to introduce this course in their institutions. Publication of a Newsletter/Journal will encourage greater participation of the educational community as a whole in these activities.

In conclusion, it may be stated that India possesses a variety of residues which can be used for meeting the growing shortages facing the country today, but the absence of a National Centre to collect the wealth of information, to co-ordinate the activities of the agro-industries and R & D institutions and to foster cooperation with regional and inter-national agencies, seems to be the main limiting factor in the economic utilization of these inexhaustible resources and creation of awareness on environmental pollution problems.

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