Fire, Wood, Water: Reaping the Benefits...

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EXCHANGE OF ENVIRONMENTAL EXPERIENCE SERIES —BOOK ONE

Fire, Wood, Water: Reaping the Benefits

Exchange of Environmental Experience Series —Book One

United Nations Environment Programme
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PREFACE

Sustainable development, as many of us have recognised, depends on a thorough knowledge of the world around us. Only if we know what are the extent of our resources—and the limitations placed on them—can we begin to assess our real potentials.

A crucial area in the quest for knowledge is the availability of information. Reliable information is required as a basis for all decisions. The United Nations Environment Programme has operated an international environmental information system for the past ten years. From humble beginnings, INFOTERRA has developed into one of the largest information supply systems on the environment in the world. It now handles about 13,000 queries a year through its national focal points in 133 countries and its Programme Activity Centre at UNEP Headquarters in Nairobi. Most of the information it supplies is in the form of documents — which themselves are the result of research in the countries and United Nations agencies which participate in INFOTERRA activities.

In assessing the results of INFOTERRA services at the end of its first decade of operations, it became clear that what was sometimes needed was inspiration based on other people's examples and experiences. Hence this new series of short books. The *Exchange of Environmental Experience* series seeks to promote another level of understanding based on actual experiences — both the good and the bad. Hopefully, lessons will be learned on new or adapted approaches which will enable many who are engaged in national development everywhere to meet their goals.

Our goal is common: to provide a better world based on a thorough understanding of our potentials, and our limitations. The need to develop technologies which are environmentally sound, patterns of production which are not wasteful of non-renewable resources and which recycle and reuse such resources, sources of energy which are renewable and those which pollute less, assume their importance. Here is the important role for the exchange of environmental experience: experience of being miserly with our limited resources, of conserving and reusing, needs to be translated into concrete techniques, and knowledge of these techniques made available to the world community at large.

I hope this series of books will stimulate widespread public interest, and spur on those who can help devise policies for a better world.

Mostafa K. Tolba
Executive Director
United Nations Environment Programme

FOREWORD

By Woyen Lee
Director, INFOTERRA Programme Activity Centre
United Nations Environment Programme

The series of books, entitled *Exchange of Environmental Experience*, grew out of a recognition that a great deal of valuable experience on the environment was being shared through the INFOTERRA network—but perhaps much of this information warranted a wider audience. The substantive information given to one user upon request might be of interest to others. As thousands of questions on the environment are answered by the INFOTERRA network every year, surely there could be a wider audience?

INFOTERRA has been mandated by successive sessions of the Governing Council of the United Nations Environment Programme to provide the pathway to answer questions and to exchange experience on the environment. This has been achieved through the establishment of an international network of information systems in 133 countries and co-ordinated by the INFOTERRA Programme Activity Centre. The annual number of queries processed by INFOTERRA passed 12,700 in 1986 alone. The goal of providing a viable query-answering mechanism thus has been met. The time has now come to stimulate environmental awareness, and in particular an awareness of the kinds of experience that are available through INFOTERRA. The medium chosen is this modest series of books.

INFOTERRA PAC is indebted to the kind contributors whose work is shared on the following pages. Without them, and without our national INFOTERRA partners—focal points and information sources alike, the free exchange of environmental information and experience would still be a dream.

This volume contains scientific findings, an historical overview, an analysis of managerial methods and the results of experimentation. While the views are those of the authors, and do not necessarily reflect national policies or receive the endorsement of UNEP, the information contained within these covers represents experience from many corners of the world.

It will be up to the reader to decide what ideas may be adopted. And that underlines a fundamental requirement: that we open our minds to applicable solutions to our environmental needs. When that happens, the title chosen for this first book, *Fire, Wood, Water: Reaping the Benefits...*, will become abundantly clear.

At UNEP we have come to realize that existing and emerging environmental problems are, and will continue to be, the product of inter-relationships between a whole range of factors. Simple and apparently direct solutions do not always produce the expected results. As a consequence, solutions must also involve a whole range of elements. The key in the search for alternative solutions is information. With the publication of this illustrative book, I invite you to join the 56,000 others who have become INFOTERRA users.

Nairobi, March 1988.

INTRODUCTION

One of the problems associated with the compilation of a book such as this is knowing where to begin. What areas of experience should be chosen? Should each volume contain material pertinent to one subject, such as soils or water, or should a wider range of subjects be included in each book? Should scientific and technical literature, only, be included—or should an attempt be made to satisfy as wide a group of readers as possible by presenting non-technical matter? Since over 12,000 queries have been processed by the INFOTERRA network each year in the recent past, the choice of a few articles appeared difficult.

These matters resolved themselves in the course of corresponding with the authors, both for this and future books in the series. Some potential authors expressed support but were unable to provide the necessary information within our deadlines. Some sent material already published elsewhere and generously donated the rights to reprint. Others immediately conducted research into the chapters we requested, compiled their studies and forwarded us their manuscripts.

The results can be seen on the following pages.

INFOTERRA is not in a position to judge whether any of the suggestions contained in this book will be universally applicable. Probably they are not, given the varied social, economic and geophysical conditions of our global community. But every case, as presented, represents valid research and experience for the country or region of its origin. And, as conditions in one part of the world are usually similar to those somewhere else, these experiences are pertinent to many of those researchers, students and decision-makers alike, involved in finding acceptable solutions to existing environmental problems.

Rice as a staple in the diet of almost half the world's population provides the starting point for this the first in the series of books on the exchange of environmental experience. One of the by-products of rice is straw—and that straw is widely used in Asia as one of the raw materials in the production of paper. But rice straw used in the pulp and paper industries presents potentially damaging consequences. Now a new technology developed in Tianjin, the People's Republic of China, addresses the problem. 'Wet Cracking' of the liquified pulp, as part of the manufacturing process, offers a newly developed solution. On the other hand, rice husks themselves, often merely burned or used as land filler or mulch, can also be used profitably in the construction of buildings. Research from India demonstrates that adhesive properties, similar to that of portland cement, can be found in rice husks after appropriate treatment. This alternative to waste has social as well as economic benefits.

New and renewable sources of energy receive wide attention now that we have become aware of the environmental ravages of carbons, sulphurs and other emissions, not to mention the dangers associated with nuclear accidents. Many technologies exist. But too many technologies are out of the financial reach of developing nations. One chapter, compiled by a staff member at the Asian Institute of Technology in Bangkok, examines the various experiences of biogas production in Asia. The design and construction of biodigesters is examined, as are national policies towards their use and management. Another chapter outlines the experiences of geothermal energy use in Iceland—a pioneer in domestic space heating. That chapter describes the evolution of geothermal energy use in the country, including modern industrial applications. Many of those practices are now beginning to be employed in a number of countries in the developing world.

Another element examined is water. Technologies available in the developing world are examined for their usefulness in providing cleaner, and safer, water supplies. Staff members at the Asian Institute of Technology have produced an analysis of pertinent experiences from rural areas, giving the benefits and drawbacks of different water purification systems. As water also flows from surface sources, the WASH Operations Center has provided a detailed, step-by-step approach to selecting and then capping springs. The method demonstrated is the result of many years of experience in training water technicians in the developing world and it requires little more than basic building skills.

Environmental management, both as a concept and in practice, is presented by a member of the Centre for Environmental Management and Planning in the United Kingdom. The experiences of developed and developing countries alike are compared, and clear guidelines are included which should enable students and administrators to examine their national commitment to an environmentally safer world.

While environmental management might appear to be an after-thought in the compilation of this book, nothing could be further from the truth. The common theme throughout this volume is one of environmental consciousness. Unless we learn to manage our resources sensibly now, future generations will reap no benefits. Instead, they will be condemned to paying our debts.

Perhaps that is what the exchange of environmental experience is all about.

TREATMENT OF BLACK LIQUOR FROM ALKALINE RICE STRAW PULPING BY MEANS OF WET CRACKING

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INTRODUCTION

In China and other developing countries, alkaline pulping has been adopted in most pulp and paper mills and straw, especially rice straw, is widely used as the raw material for paper making in many mills. Due to the high content of silicon in rice straw, silicon is converted into Na_2SiO_3 during cooking. In the conventional process, Na_2SiO_3 causes difficulties to evaporation, combustion, causticization and the recovery of white mud. With silica accumulating cyclically, silicon interference becomes so serious that recovery of the black liquor from rice straw has not been tackled so far.

Another main reason that many straw pulp mills fail to recover black liquor with the conventional process is the smaller scale of these mills. The conventional system requires a complicated production process, lots of equipment and complex operational skills. As a result, workshops set up in small pulp mills to recover the black liquor with the conventional process require vast investment, but have no economic benefits.

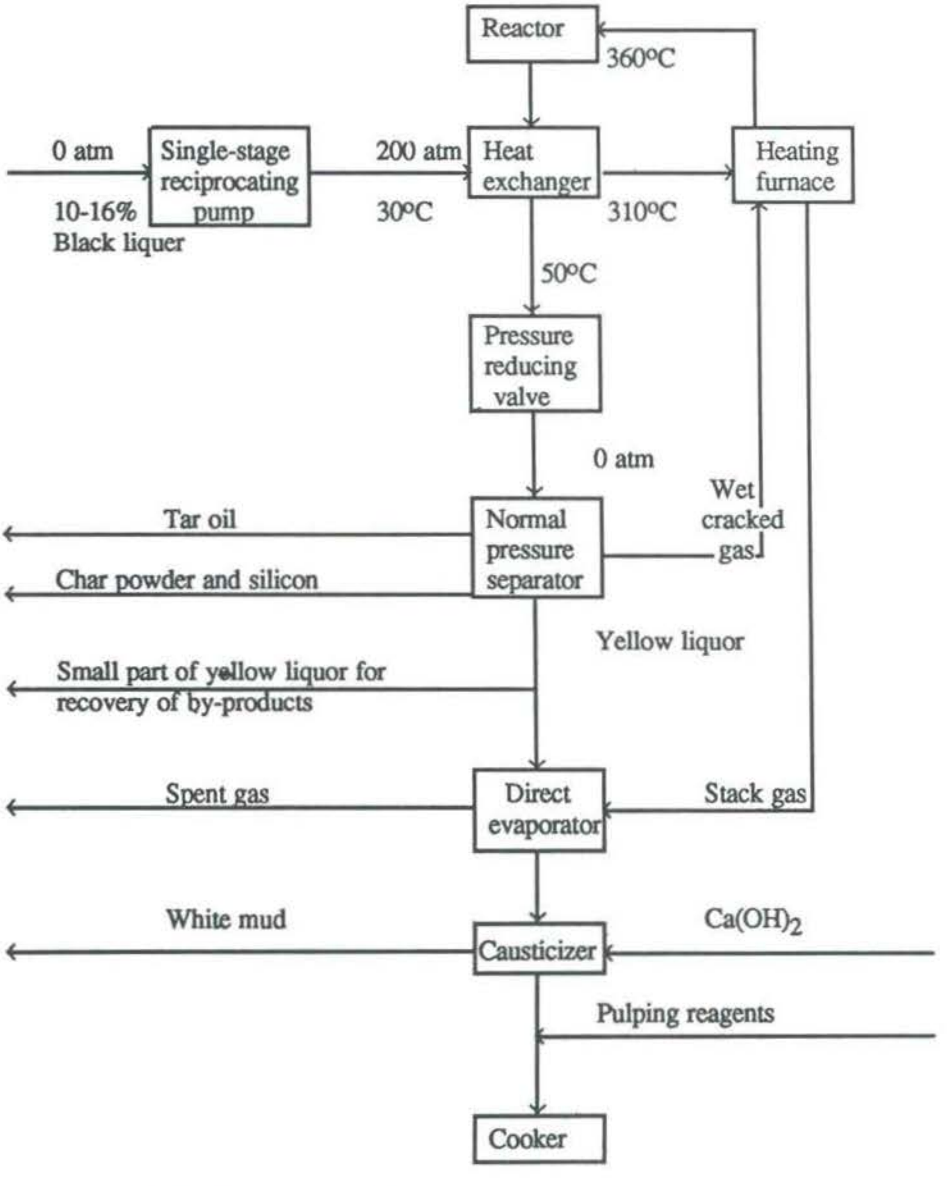
Because of the reasons mentioned above, most small alkaline straw pulp mills are unable to recover the black liquor and have to drain it off, resulting in loss of alkali and organic values, furthermore, causing heavy environmental pollution. Papermaking is one of the major industries causing environmental damage in some countries, especially where straw is used as the main raw material. For these countries 90% of the total pollution caused by the paper-making industry comes from black liquor.

The wet cracking process developed by us is suitable for the treatment of black liquor of rice straw and other non-wood fibrous materials. At high temperatures and high presssure, wet cracking reaction takes place in the black liquor without the need for reagents to be added. Organic matter in the black liquor can be converted into fuel and other by-products; Na_2SiO_3 can be coverted into silicon and then removed. With organic matter and silicon separated and removed, regenerated reagents and water can be reused cyclically, and the environmental pollution problem caused by the black liquor is avoided. The wet cracking process requires a simpler process, simpler operational skills, and less construction investment, so the process is suitable for mills on any scale, although particularly for small straw pulp mills.

In 1979 we began to work on the treatment of black liquor coming from alkaline rice straw pulping by means of wet cracking. We succeeded in batch trials in 1980. A continuous treatment system with a capacity of 3 to 4 m^3 of black liquor per day was designed and manufactured in 1981, assembled and came into trials in 1982. In 1985, we succeeded in continuous pilot trials, and thus established the new technology of wet cracking for continuous treatment of rice straw black liquor. In 1985, we applied a patent for this invention in the People's Republic of China. We intend to design a black liquor treatment workshop for a mill which has a capacity of 5,000 tons of alkaline rice straw pulp per year.

Flow Chart and Technological Conditions

The technological process and conditions for the wet cracking process for the treatment of black liquor.



Vegetable fiber material: rice straw
Pulping method: alkaline pulping

Technological Properties

1. With wet cracking, it is not necessary to add any reagents for the treatment of black liquor of rice straw and other straw.

2. The residence time of black liquor in the reactor is 20, to 30 minutes.

3. Wet cracking reaction products are uniform in high pressure equipment, no solid sediment accumulates.

4. Wet cracking reaction products are cooled down 50°C by the heat exchanger once.

5. Wet cracking reaction products undergo pressure reduction once to atmospheric pressure through a pressure reducing valve.

6. The viscosity of yellow liquor is the same as that of water, so at atmospheric pressure and 50°C, there is no technological difficulty for the separation. By precipitation, wet cracked gas, tar oil, yellow liquor, char powder and silica are separated only once.

7. A small part of yellow liquor is drawn from the liquor system to recover by-products.

8. The residual heat of stack gas is used to evaporate yellow liquor by direct contact.

9. Most yellow liquor is heated to its boiling point and agitated for 30 minutes, releasing CO_2. The wet calcination converts 90% of $NaHCO_3$ into Na_2CO_3. After the wet calcination, the yellow liquor is causticized by lime to become white liquor, replenished with a part of the pulping reagents, and the white liquor is reused in pulping.

10. There is no undesired effect on yield, strength, or whiteness of bleached pulp when recovered alkali is used in pulping.

Source and Characteristics of the Black Liquor

The black liquor of rice straw comes from chemical pulping by digester with a volume of 25 m^3.

Alkali charge: NaOH 12%
Liquor ratio: 1:3
Cooking pressure: 4.2 atm
Cooking temperature: 153°C
Cooking time: heating to 153°C within one hour and maintaining the temperature for one and a half hours.

The black liquor comes from the wash department. The solid content is 10 to -16%. The specific density is 8-10°Bé (20°C). The pH of the black liquor is 10.

Wet Cracking Reaction Products

1. Wet cracked gas, yield: 100-150 m^3 per ton of organic matter in black liquor.
Compositon:
Co_2 =30-35 %,
H_2 =20-24%,
CH =12-14%,
C_2H_6 & C_2H_4 =11-13%,
C_3 =8-10%,
C_4 =6-8%,
C_5 =3-5%.

   Wet cracked gas is colourless, transparent, and its flame is blue in colour when being burnt.
Heat content: 6000-6800 kcal/m^3 gas.

2. Tar oil, yield: 100-120 kg per ton of organic matter in the black liquor.

3. Char powder and silica, yield: 50-150 kg per ton of organic matter in the black liquor. There are tiny solid particles, black and brown in color.

4. Yellow liquor, specific density: 1.065, pH: 7.5. This kind of liquor is clear, transparent and lightly yellow. We have named it "yellow liquor". Yellow liquor comprises mainly $NaHCO_3$, followed by NaAc, and a small amount of $NaCo_2H$.

5. The stack gas and gas coming from wet calcination of yellow liquor contains a great amount of CO_2, which can be used to produce light $CaCO_3$ and other by-products.

6. A small part of yellow liquor is drawn from the wet cracking system to produce acid, salt, ester by-products containing NaAc and $NaCo_2H$. After wet cracking treatment, organic matter is reduced by 80-95%, and silicon is reduced by 96-99%. Most of the total alkali in the black liquor (55-80%) is recovered in the form of $NaHCO_3$.

Environmental Protection

1. By means of wet cracking, organic matter and silicon in black liquor are separated and removed, pulping reagents and water are reused cyclically in cooking and thus are no longer poured out to pollute the environment. Environmental pollution stemming from black liquor is eliminated. Wet cracking for the treatment of straw pulp black liquor basically cuts the pollution problem caused by contaminated and condensed water produced by the evaporation in the conventional process.

2. In the wet cracking process, the spent gas which is discharged contains only nitrogen, carbon dioxide and water vapor, which are not harmful to the environment. This compares favourably with the conventional process in which the alkaline dusts of stack gas coming from burning furnaces lead to secondary pollution.

3. In the wet cracking process, white mud contains an extremely small amount of silicon. White mud can be calcinated, and reused cyclically which makes it possible to eliminate secondary pollution of white mud caused by the conventional process.

Economic Evaluation

The wet cracking process has many advantages over the conventional process. On the one hand, the reciprocating pump is standardized, using three high pressure units of typical design and made from currently available materials. On the other hand, it requires a simpler production process, less equipment, less space and a lower construction investment.

It is easy for the wet cracking process to be operated and controlled automatically. The wet cracking process requires less operational skill and operational personnel, and it reduces the wage cost.

Wet cracking reaction requires no chemical reagents, it needs only the heating of black liquor up to reaction temperature after the pressure is increased by the reciprocating pump. The reciprocating pump is single-stage and electricity consumption is low. One of the principal advantages of wet cracking is the high efficiency of heat energy. Eighty-five percent of the energy to heat black liquor is supplied by the heat exchange with wet cracking reaction products, the rest (15%) is acquired from the combustion of wet cracked gas in the heating furnace. Wet cracked gas, tar oil and char powder can be used as fuel also. In a word, the energy needed is more than self-supporting. In the conventional process, a large quantity of oil is needed to keep the incinerating furnace temperature constant.

In contrast with the conventional process, in which all organisms are burnt completely, the wet cracking process converts organic matter into many kinds of wet cracking reaction products, such as wet cracked gas, tar oil, char powder, NaAc, $NACO_2H$, CO_2, etc. which can be treated again to produce various kinds of by-products. Thus, the economic effect is superior to that of simple combustion.

For the treatment of straw pulp black liquor by means of wet cracking, the overall economic evaluation is: it requires a lower construction investment and operational cost; no additional reagent is needed; heat energy is more than self-supporting; by-products can be recovered and better economies achieved.

Versatility of Application

Wet cracking is suitable for the treatment of black liquor from rice straw, other kinds of straw and hardwood pulping.

Wet cracking is suitable for mills of any scale, but particularly for small ones which have a capacity of 3,000-5,000 tonnes of pulp per year.

Wet cracking is suitable not only for the treatment of black liquor from straw chemical and semichemical pulping, but also for the treatment of black liquor resulting from pulping with other vegetable fiber materials through the prehydrolysis process.

For rice straw chemical pulp, the alkali charge in pulping is about NaOH 12%; after the prehydrolysis, substances in it have been dissolved by about 25%, so the alkali charge required is only NaOH 6 to 7%. By means of wet cracking, the effect of the treatment of black liquor from chemical straw pulping with the prehydrolysis is much better than that without the prehydrolysis; organic matter can be removed by 85-95%. The amount of alkali in the form of $NaHCO_3$ can be recovered by up to 80-90% of the total alkali in the black liquor. That is to say, alkali consumption in the process without alkali recovery is NaOH 12%; alkali consumption in the process with wet cracking and the prehydrolysis is only NaOH 1.5 to 2%.

The wet cracking process is suitable for pulping reagents: NaOH, NaOH-AQ, NaOH-Na_2SO_3-Na_2S, and although the pulping reagents are different for the three reagents, the technological process, conditions and equipment are basically the same for the treatment of black liquor.

In NaOH-Na_2SO_3-Na_2S pulping, the amount of sulfur compound in the total alkali should be below 25% (calculated with Na_2O). Because of the low level of sulfur content, wet cracked gas contains a small amount of CH_3SH, $(CH_3)_2S$, and H_2S, sulfur exists in the yellow liquor in the form of NaHS. With the pressure reduction of wet cracking, reaction products carried out at about 50°C volatility of H_2H is limited. When wet cracked gas containing sulfur is burnt in the heating furnace, the sulfur compound in the gas is converted into SO_2, which is absorbed, converted into Na_2SO_3 and dissolved by yellow liquor. Either Na_2S or Na_2SO_3 is expected to be a main desired sulfur compound. If the former is expected, Na_2S and NaOH are added to the regenerated white liquor. If the latter is expected, Na_2SO_3 and NaOH are added to the regenerated white liquor. Another method is to burn sulfur in the heating furnace to produce SO_2, which is absorbed by yellow liquor and converted into Na_2SO_3.

CONCLUSIONS

Wet cracking is suitable for rice straw, other kinds of straw containing vegetable fiber materials, and is suitable for NaOH pulping, NaOH-AQ pulping and NaOH-Na_2SO_3-Na_2S pulping. Organic matter and silicon in the black liquor can be separated and removed. Reagents in the black liquor can be separated and removed. Reagents in the black liquor and water can be regenerated and reused cyclically. Environmental pollution resulting from the black liquor of straw pulp can be eliminated. Wet cracking is a simpler process and requires less construction investment; the whole process can be manipulated and controlled easily. Furthermore, it makes recovery of many kinds of by-products possible, has important social effects and certain economic benefit. Wet cracking is suitable for straw pulp mills of any scale, but particularly for small ones and is a promising method to treat black liquor of straw pulp.

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RICE HUSK ASH MASONRY BINDER — RHAM

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INTRODUCTION

The technology for the manufacture of Rice Husk Ash Masonry (RHAM) binder developed by Cement Research Insitute of India (CRI) aims at the utilisation of huge quantities of paddy waste available from the hulling of rice either in the fields or at the mills for simultaneously producing a rural binder material. RHAM binder is essentially a lime pozzolana mix with the difference that the pozzolana, which in this case is rice husk ash, is far more active than most of the other known pozzolanas, and in this context RHAM binder offers an attractive alternative to ordinary portland cement for masonry purposes. RHAM binder can fulfil the requirement of binder material for most of the constructional purposes (excepting RCC) in the rural sector particularly, and also to a considerable extent in semi-urban areas, augmenting the short supply of portland cement. This chapter deals with the essential features of the utilization of rice husk for making binder, including various available technologies in India and abroad and their influence on the activity of the ash produced; the scientific approach for developing appropriate technology by CRI for producing highly active and easily grindable ash for manufacturing rice husk ash binder; and the special place of rice husk ash amongst manufactured pozzolanas both from the point of view of high pozzolanic activity and disposal of an agro-industrial waste, rice husk, which otherwise presents ecological problems.

Rice Husk as a Potential Source for Pozzolana

Rice husk contains up to 30 percent inorganic matter, most of which is silica. The technology of RHA based binders utilizes this silica present in rice husk mostly in an amorphous state. The husk on incineration yields rice husk ash (RHA) which has varying degrees of pozzolanicity depending upon the conditions under which it is produced. Considerable effort has therefore gone into investigations aiming at producing highly active ash from rice husks for utilization and to exploit its pozzolanic activity in making binder material. Research and development efforts in this field were first discussed at international forums such as the International Conference on Rice By-products Utilization, Valencia 1974, which evinced a lot of interest in practically all the rice producing countries and even has drawn the attention of UNIDO who have organised workshops on industrial utilization of agro wastes for making cement at Peshawar (1979) and Alor Setar (1979).

It is in this context that rice husk ash based binder materials and the development of technology related thereto was considered important and of direct relevance to a country like India which is a major rice producing country of the world, accounting for nearly one-fourth of global paddy production. What makes development of such a technology more relevant is the renewable nature of this source of energy and binder materials.

Technological Developments

The technology developed abroad, particularly in the United States of America, is quite sophisticated, consisting of an integrated plant for incinerating the hulls to produce rice husk ash for producing highly priced special cement and simultaneously recovering thermal energy for other useful work. However, the capital investment of the plant based on this technology is very high and as such is not considered appropriate to the Indian situation.

In India efforts in the past have been mainly directed towards producing clinker and lime based binders utilizing pozzolanic activity of rice husk ash. In this regard, the following technologies have been reported:

i) Intergrinding of boiler ash from rice husk fired boilers with lime.
ii) Firing of lime-rice husk-clay mixture and fine grinding of the calcinated product.

Rice husk ash available from boilers, as tested for pozzolanicity and lime reactivity, indicates low pozzolanic activity and it has to be ground very fine to increase its reactivity for use in producing rice husk ash binder under technology (i) above. It is obvious that the grinding energy requirement is very high. On the other hand although the grinding energy and costs thereof for the technology under (ii) above are lower than the former , the activity is also lower and so is the strength development in the binder produced from it.

Research and Development Work at CRI

In view of the above, research and development activities at CRI towards the utilization of rice husk for making binder were therefore mainly directed towards the following objectives:

(i) Optimization of conditions of incineration of rice to produce highly active ash, instead of using by-product ash from boilers using husk as fuel.

(ii) Studies relating to the variability in composition of the ash and reactivity obtained by incinerating different strains of rice cultivated under varying agricultural practices.

(iii) Design and development of a low cost incinerator for producing highly active ash.

(iv) Comparative evaluation of ash obtained from husk fired boilers *vis-à-vis* laboratory incinerated ash for reactivity and grindability.

(v) Formulation of RHA based binders.

Highlights of the research and devlopment efforts are summarized as follows:

(i) According to investigations at CRI, rice husk ąsh obtained both under controlled and uncontrolled burning have indicated that the reactivity of ash is a function of the state and form in which silica exists, and it has been established from experiments that while the rice husk obtained under uncontrolled burning, as in open firing or in boilers, contains mainly cryslobalite and ∞-quartz, the ash obtained under controlled incineration delineated by CRI contains silica distributed predominantly in an amorphous state and this explains the differences in their relative activities. These observations have been further confirmed by lime reactivity and pozzolanicity tests: while RHA obtained under controlled incineration is highly pozzolanic, with a lime reactivity of ±90 $kg/cm,^2$ the ash obtained under uncontrolled burning is non-pozzolanic with a lime reactivity of ± 20 $kg/cm.^2$

Further, grindability studies have indicated that the grindability of rice husk ash is a function of the thermal treatment given to the husk. Uncontrolled burning yields ash which is hard to grind while ash obtained under controlled incineration is easily grindable. The energy consumption ratio for grinding to a specific fineness of ash from boilers and from controlled incineration is approximately 3:1.

(ii) Optimisation of various parameters like temperature, time and air requirements during incineration of rice husk, and mode of cooling of rice husk ash for producing highly active ash.

(iii) Design of two types of incinerators and standardization of operational parameters for producing 0.5 tonnes of active ash per day.

(iv) Formulation of clinker and lime based binders based on active ash obtained from incinerators with typical performance characteristics.

Rice Husk Ash Masonry Binder - RHAM

RHAM binder is essentially a lime pozzolana binder.

Factory made lime pozzolana mixtures conforming to IS* ; 4098-1967 have been classified and are recommended for following applications:

Type	*Applications*
LP40	Masonry mortars and plasters of 30-50 kg/cm^2 grade and foundations concrete
LP 20	Masonry mortars and plasters of 15-30 kg/cm^2 grade and foundations concrete
LP 7	Masory mortars and plasters of 7-15 kg/cm^2 grade

Performance characteristics of RHAM binder produced with CRI technology are superior to LP 40 grade lime pozzolana mixtures and as such can be used for most of the construction activities (excepting RCC) with advantages of improved workability, bond strength and higher load carrying capacity.

*IS = Indian [Bureau of] Standards

CEMENTITIOUS BINDER FROM WASTE LIME SLUDGE AND RICE HUSK

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INTRODUCTION

A new hydraulic binder possessing properties similar to portland cement has been developed from rice husk and waste lime sludge of the sugar, acetylene, paper industries etc. The binder can be used in place of ordinary cement for certain construction operations. The production of the binder is quite easy and can be adopted on a small-scale industry level. The binder is consequently cheap and can be manufactured in the rural areas by the villagers as no special skill is needed in its manufacture. This chapter briefly describes the preparation, properties and some important applications of the binder.

Method of Preparation

(a) Materials : The two basic raw materials for the process are rice husk and waste lime sludge. Rice husk should be fine or in a crushed state. Husk obtained from paddy hullers can be directly used but that produced in the full shell form by the rice mills should be passed through a huller or a grinding machine before use in the process. The other ingredient, lime sludge, should be in dry and powdery form.

Waste lime sludge available in the area and rice husk are dry mixed together roughly in equal amounts by weight. The required amount of water is added to the dry mix for manually making balls/cakes (like those of animal dung). These balls/cakes are put out in the open for drying before burning. It should be noted that the balls/cakes possess sufficient strength and do not disintegrate during handling or firing.

(b) *Firing* : The dried balls/cakes are next fired in the open on a "jalli" (grating) base of a clamp or in a trench. A clamp is made with two side walls of bricks and a "jalli" base is provided by placing iron bars in parallel positions at a distance less than the minimum diameter of the balls/cakes and at a height of about 10 to 20 cm from the ground.

The trench is made by arranging bricks in the same manner as trench kilns are made. Small openings of 5-10 mm are allowed between the bricks of the trench wall to allow sufficient air for good firing of the material. The height of the trench walls above the base should be around 75 cm and the maximum width of the trench is kept around 100 cm. The length of the trench or clamp depends upon the quantity of the material to be fired. Once the material is fired at one end, fire travels easily so as to make the process of firing continuous. Rice husk not only acts as integral fuel but also provides *in-situ* silica for the lime produced during firing.

(c) *Grinding* : The fired material obtained is a soft powder. Its reactivity like other hydraulic binders increases with increasing fineness. It is, therefore, ground by a grinding device preferably in a ball mill to achieve sufficient fineness. It has been found that the grinding effort which produces a fineness of 3000 sq cm/gm in portland cement clinker in 6 hours is sufficient to grind this material to a fineness of 8000 sq cm/gm in just half to one hour.

Properties

(i) *Chemical Composition:* The binder thus obtained is based essentially on lime and silica with inherent characteristics of lime-based compositions. Given below are some of the important properties of a typical binder based on sugar press-mud. The basic chemical composition of the binder is governed by the composition of the lime from which lime sludge is derived. There is a simple addition of silica into the product along with 3-6 per cent of unburnt carbon in it. Any calcarious waste which contains at least 45 per cent calcium oxide on ignited basis is suitable for making the binder. However, it should not have sulphur trioxide content more than that permitted for hydraulic cements i.e. 2.75 per cent. Lime sludge from caustic soda recovery plants of the paper industries should not have free alkali more than 0.50 per cent.

(ii) *Bulk Density:* The dry bulk density of the material obtained on firing is about 360 kg/m^3 which increases to 700 kg/m^3 on grinding.

(iii) *Setting Time*: The setting times determined by Vicats apparatus as per IS*: 269-1958 "Specifications for ordinary, rapid hardening and low-heat portland cements" are:

Initial setting time: 60-90 minutes (Approx.)
Final setting time: 480-600 minutes (Approx.)

(iv) *Water Retention:* The following data has been obtained when the binder was tested for water retention property as per IS; 2250-1965 "Code of practice for preparation and use of masonry mortars", for percentage of original flow after suction for various binder-sand mixes:

Binder	:	Sand	%flow
1	:	1.5	71
1	:	2	65
1	:	3	60

(v) *Compressive Strength:* The crushing strength values of the binder was tested as per IS: 712-1973 "Specifications for building limes", using one part of binder and three parts of standard sand. The results for the binder made from different sludges are:

Curing period	Compressive strength (kg/cm^2)		
	Sugar sludge	Carbide sludge	Paper sludge
7 days	31.5	23.8	18.0
14 days	40.6	27.5	23.2
28 days	50.0	35.5	28.9

All the sludges have been found to pass the compressive strength requirements for Class A lime (eminently hydraulic lime) which are 17.5 kg/cm^2 and 28.0 kg/cm^2 for 14 and 28 days respectively.

* IS: India [Bureau of] Standards

The binder also passes the compressive strength values when tested as per IS: 4098-1967 "Specifications for lime pozzolana mixture". The results obtained are:

Curing Period	Compressive Strength (Kg/cm^2) (I.S. 4098)		
	Binder : Sand	LP-20	LP-7
7 days	11.00	10	3
28 days	23.50	30	7

(vi) *Soundness:* The soundness of the binder when tested as per IS: 4031-1968 "Methods of physical tests of hydraulic cement" is as follows:

The measurement of expansion in Le-Chateliers moulds was found to be 1.5 mm as against the specified limit of 10 mm (maximum).

Typical Applications

(a) *Masonry Mortars & Plasters:* The crushing strength, water retention and quick setting values of the binder indicate the suitability of the material for masonry mortars and plasters. Since it is a reactive mixture of lime and silica, it has many good points of lime-based compositions over portland cement in being more plastic, cohesive and less harsh. On account of the quick setting nature of the binder, these mortars are useful for the purpose of plastering and are capable of taking up stresses due to shrinkage and temperature in the masonry more evenly. For these applications, binder: sand composition of 1 : 2 by volume is recommended.

(c) *Concrete:* Ordinary concrete of the binder with sand and coarse aggregate can be made in a way similar to that of portland cement. This concrete was found to set within 24 hours after casting. The compressive strength of the concrete blocks 29 x 19 x 9 cm size of different compositions prepared with this binder are given below:

Mix binder:sand:coarse agg.	28 days com. strength kg/cm^2		Drying Shrink-age	Moisture Movement
	Comp.factor=1	Comp.factor=0.75		
1 : 1 : 2	85	102	0.02	0.01
1 : 1.5: 3	50	70	0.02	0.01
1 : 2 : 4	19	31	—	—

These values are being given for designing mixes for typical applications for unreinforced concrete such as in foundations and floors, precast hollow or solid concrete blocks for light load bearing purposes, etc.

(c) *Pressed Bricks:* The binder is specially suitable for making bricks and blocks with sand under pressure using a semi-dry mix. The results of compressive strength on the briquettes

(10 x 5 x 2cm) of the binder with graded sand in the ratio of 20:80 are given below.

The briquettes were cast at two forming pressures, i.e. 150 kg/cm^2 and 300 kg/cm^2.

Forming pressure kg/cm^2	Compressive strength kg/cm^2		
	Cured under water for 28 days	Steam cured for 3 days	Autoclaved at 10 kg/cm^2 for 6 hours
150	127.8	144.0	204.0
300	214.0	243.7	328.5

The full size bricks are expected to possess compressive strength to the extent of 65-75 per cent of the above values. Considering the specified compressive strength of 150 kg/cm^2 as per IS: 4139-1967 for sand-lime type bricks, it is possible to make suitable bricks.

(d) *Stabilized Soil Bricks:* Like lime and portland cement the binder can be used to stabilise soil. Full size bricks of two ilietic soils have been made on hand operated brick making machine and tested for various stabilization characteristics:

Soil	Binder, % by weight	Dry bulk density g/cc	Comp strength (28 days) kg/cm^2	Water absorption %
A	10	1.82	26.2	12.9
	15	1.80	37.5	13.0
B	10	1.87	29.0	12.2
	15	1.84	40.3	12.8

From the above data, it can be seen that bricks made from both soils including soil B (which is very sandy and is unsuitable for making burnt bricks) with 10% binder by weight pass the compressive strength requirement (18 kg/cm^2) as per IS: 1725-1960 "Specification for soil cement blocks used in building constructions."

Novel Features of the Binder

1. The binder has been prepared entirely from the waste products capable of giving lime and silica on firing. These are available in huge quantities as industrial and agricultural wastes.

2. As the binder has lime as one of the principal components, it possesses the qualities of lime based composition, such as improved water retention, workability etc, coupled with quick setting properties unobtainable with ordinary lime-pozzolana mixtures.

3. The binder can be used in making ordinary concrete and concrete for sub-flooring and terracings in place of lime concrete masonry mortars and plasters, soil stabilization, load bearing concrete blocks and pressed and stabilized bricks, etc.

4. The binder is potentially a suitable material for low cost housing. Since its method of making does not involve special skill and machinery it can be made and used as a partial substitute

for cement on a small scale level on a self-help basis.

Testing of Materials

The results given Under 'Properties' and 'Applications' are typical for a sample of pressed mud. For different types of waste lime, the results may vary, i.e. the values may be better or otherwise. In such cases, it is considered necessary to check the sample for its suitability for making the hydraulic binder and to find out the compositions for best results. Necessary investigations for this have been arranged at the Central Building Research Institute, Roorkee, India.

BIOGAS DEVELOPMENT AND APPLICATIONS IN SOME COUNTRIES IN ASIA

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Introduction

Biogas should not be confused with other combustible gases produced from biomass like producer gas or wood gas. Biogas is generated by bacterial action under anaerobic conditions at ambient temperatures. It consists of about 99% of methane (CH_4) and carbon dioxide (CO_2), average concentrations being in the order of 65% CH_4 and 34% CO_2. Methane is the combustible component and makes it suitable for cooking, lighting and running engines. At the average composition, biogas is slightly heavier than air. Methane and CO_2 do not smell but they contain other minor components like hydrogen sulfide, mercapthanes or volatile acids, thus leaks can be detected. Biogas is explosive when mixed with air if it is within the range of 5 to 15% biogas in air. Most of the biogas is produced from animal manures, and smaller quantities are produced from agricultural residues such as rice straw and corn stalks, or fresh plants such as water hyacinths. More than 90% of all biogas plants are of family scale, the rest at farm and industrial scale.

This paper describes experiences at the family scale and focuses on four countries in the Asian region: China, India, Nepal and Thailand.

All these countries pay attention to biogas technology (BGT) at governmental level, but with different intensities. The first priority is to save natural resources. The depletion of forests is enormous, as wood consumption is much higher than the natural production. Another reason is to reduce environmental pollution caused by farms raising chicken, pigs or cattle etc.

BGT is in the stage of dissemination. In parallel, research is undertaken at various levels, for example, improved construction, design and standardization, new construction materials, biogas utilization, effluent and slurry utilization as fertilizer, and for heating devices in cold climates. Field research, i.e. monitoring and evaluation, is of increasing importance. Acceptance, life-time (operating and non-operating digesters), problems in maintenance and operation, digester sizes and land holding, savings in time for cooking and wood collection, training and man power requirements, and problems with subsidies are of high priority. Results in research and development (R & D) give the necessary feedback to dissemination programmes. The R & D infrastructure and programme is well developed in China and India.

BGT is not a home-made technology but deserves a certain degree of organization and coordination. This is being examined in the following chapter.

Administrative demand

In China and India, the organization and coordination of governmental support was strengthened and reaches down to village level. Such support is as essential as a reliable technology, because biogas development is a long term task. Special agencies should take care of the development of policies, programmes and plans and their execution. Funds and materials for construction, particularly cement, have to be distributed and their distribution be organized. R & D projects have to be organized and coordinated and information on new technologies has to be collected and disseminated. Training of trainers and of technicians has to be organized and executed. Even when one of these items is missing or poorly developed (lack of staff, lack of commitment of staff) the whole programme is likely to fail.

In China, India and Nepal, biogas activities concentrate on provinces and states with the highest potential in regard to raw materials and climatic conditons. Such priorities were set when starting with national biogas programmes. These are sometimes coordinated with programmes on improved cooking stoves, reafforestation, or rural electrification. In China, these include 16 out of 21 provinces, with Sichuan as the main province. In India, 19 states out 21 have been selected, and Maharashtra developed the most important one. In Nepal it is the Terai (plain belt). In Thailand, activities have focussed on three regions (Central, Northeast and South) out of 5 but without having priority criteria.

India has decided upon a "multi-model, multi-agency" approach. Governmental, parastatal and private agencies are involved, mainly in constructing two types of digesters: Janata fixed-dome and KVIC floating-drum type. In China, mainly governmental agencies are involved. In Nepal, one agency is constructing one standardized digester type. In Thailand, different designs are being constructed by different agencies without overall coordination. Thus, the success of dissemination is different in the four countries. The following tables give an overview of actual installations, the potential of biogas generation and applications, and how the four countries handle the dissemination of BGT.

Table 1: Family-sized digesters

Country	Biogas plants (No)	Size (m^3)	Rural families involved (%)	Actual construction activity (No/year)
China	5,000,000	6-10	2.5	500,000
India	650,000	6-20 ø:18	0.6	190,000
Nepal	2,100	15-20	0.07	300-400
Thailand	3,000	4-10	0.04	100-200

The number of digesters installed in China and the annual construction are average figures due to the range given by different sources.

The assessment of the potential poses problems because statistics on rural population, their income and expenditure, cattle population and number of cattle etc., per farm, availability of manures, energy consumption patterns, use of fertilizers etc., are incomplete, not updated or missing to some extent. Based on available data (1-13), the potentials may be assumed to be as given in Table 2.

In India, Nepal and Thailand, the total potential for family sized digesters is limited by either manure availability or purchasing power of the farmers or by both. Only 15 to 25% of all farmers would be able to purchase a digester. The situation in China is different. Almost all farmers in areas with a favourable climate could construct a biogas plant, for example 100% in the Sichuan Province.

In India and Nepal, the farmers have a cultural familiarity with cow manure, but no field experience with the digestion of agricultural residues. The use of night soil is taboo, thus cow manure is digested at the family-scale exclusively. Unlike the farmers in India and Nepal, the Thai peasants do not have any cultural familiarity with manures and the digestion of night soil is a taboo as well. In China, none of these constraints are known.

The potential for the replacement of traditional energy sources is the highest in China. About 80% may be replaced here whereas the potential in the other countries is about 10%.

Table 2 : Potential of biogas technology

Country	Feed stock	Number of digesters (x 10^6)	Rural families involved (%)	Biogas $10^6 m^3/y$	Replacement of firewood, etc. (%)
China	straw stalks manures	206	80	62,000	80
India }	cattle manure	10	20	14,600	10
Nepal }		0.37	15	360	10
Thailand	cattle and pig-manures	0.80	25	890	10

Source : (33)

Table 3 gives an overview of governmental support and financial assistance (33). The success of the programmes and high number of installations in China and India are due to the intensive care through governmental programmes, with an infrastructure reaching down to village level.

Table 3: Governmental support and financial assistance

Country	Item
China	Training; extension and construction; research in various fields; administration; loans to poor farmers; subsidies to community digesters.
India	Training; extension and construction; research in various fields; administration; loans to all farmers; subsidies to all farmers and for community and institutional biogas plants.
Nepal	Loans to all farmers; subsidy of all digesters (25%) was approved but not yet released.
Thailand	Training; subsidy of some demonstration plants.

Source : (33)

To have a closer look into the situation, information on training, guarantees for construction and income through construction of BG plants is given (33). Training of masons is the key for flawless biogas plants with a long service life. It should be pointed out that fixed-dome digesters have to be constructed by well-trained masons and not by farmers. This is the case in all countries except Thailand (Table 4). Training of masons and extension to farmers are well organized in China and India. In Nepal, training of masons who are supposed to work independently from the Biogas Company started recently.

Table 4: Training of masons in construction of fixed-dome digesters

Country	Trainee	Duration (days)
China	Biogas Technician	60
	Peasant Biogas Technician	30
India	Mason (master mason)	16-20
	Mason's refesher course	10-15
Nepal	Mason	45
Thailand	Farmers	7-14

Source: (33)

Guarantee for construction is provided in three countries but not in Thailand, because the farmers have to construct the digesters on their own. The Biogas Company in Nepal is charging its longest guarantee period of 7 years (Table 5).

Table 5: Guarantee for construction

Country	Guarantee	
	Years	Extra charge
China	5	no
India	2	no
Nepal	7	Rs. 118/m^3 fixed-dome
		Rs.286/m^3 floating-drum
Thailand	-	-

Source : (33)

Construction cost of US$15/$m^3$ digester volume is the lowest in China and range between US$55/$m^3$ and US$85/$m^3$ in the other three countries (Table 6). The reason for the relatively low construction costs in China may be due to the low income and expenditure level calculated in US$.

Table 6: Construction costs of family-sized biogas plants

Country	Size (m^3)	Type	Cost (US$/$m^3$)
China	6	Fixed-dome	15
India	6	KVIC	85
	6	Janata	60
Nepal	34	floating-drum	80
	10	fixed-dome	75
Thailand	4.5	fixed-dome	55

Source : (33)

In all countries, masons receive an average salary. Those people in India who organize construction and who are, in addition, involved in acquisition, dissemination and after-construction services, are getting paid well for their services. The Biogas Company in Nepal raises an overhead charge. The break even point is 360 digesters per year. The income through digester construction is presented in Table 7.

Table 7: Income through digester construction

Country	Charge	Receiver	Digester Volume (m^3)
China	Yuan40 (US$11)	Biogas technician	6-10
India	Rs.800 (US$67)	Turn Key worker	Lump sum
Nepal	Rs.1800(US$86.7)	Biogas Company	$\neq 18m^3$
Thailand	Bht.4300(US$167)	Mason	$\neq 10m^3$

Source : (33)

The farmers have to pay these "labour costs". In India, the government subsidizes these expenses by about 37% for every digester. It can be concluded that the income, especially in India, through construction of digesters, in particular floating-drum types, creates a high motivation for Turn Key workers to intensify acquisition and construction, whereas extension and follow-up are cost factors. In Nepal, construction would be similarly motivating if individual masons would be allowed to charge the above-mentioned sums. The income of masons (or expenses of the farmer) in China, again, is the lowest.

The Chinese government pays great attention to high direct benefits to the farmers. The payback period is about 4 years in case rice straw is replaced by biogas and about 9 years if coal would be replaced. The digester has to be operated for 8-10 months a year. Benefits through utilization of residues in fields, fishponds, for raising mushrooms or earthworms, reduce these payback periods further. Indirect benefits are considered to be three times higher than the direct ones. Benefit-cost ratios for farmers in India are low. Since they tend to oversize the digester, this ratio is getting even lower. On the other hand, farmers would pay more for a guaranteed durability of construction. At a certain income level, the BG as a status symbol seems to be more important than a high benefit-cost ratio.

In Thailand, the payback period would be about five years when charcoal is replaced. LPG (liquified petroleum gas) gives even a better payback period. If wood is being replaced, the construction cost should be subsidized by about 50% to get the same payback period.

Construction of biogas plants

Construction of fixed-dome digesters increased considerably in 1982 and onwards, in Nepal (18) already in 1980, replacing the Indian floating-drum design (KVIC design) to more than 90%, except in India (16) where KVIC installations still acount for about 20-30% of all plants. This development coincided with international training courses offered the first time in 1982 by the Biogas Research and Training Center in Chengdu, China. In India, Nepal and Thailand, local designs of fixed-dome digesters were developed (19, 24, 25). Construction techniques differ considerably from country to country.

There are remarkable differences in design criteria for the geometry of the fixed-dome digesters, for specific gas production from manures, daily biogas demand, etc.

Regarding the geometry of the digester, the location of the four horizontal lines is of high importance. These are a) level of inlet pit bottom, b) the highest slurry level, c) slurry level at ambient pressure, which is the most important "O" line, and d) the lowest slurry level.

The slurry level at ambient pressure and the distance to the top of the dome determines the volume of biogas which cannot be used. The volume between the highest and lowest slurry level is the useable gas volume. The lowest slurry level determines the minimum HRT of the substrates to be digested. The levels of these three lines, and thus the volumes of unuseable and useable biogas differ greatly from country to country. In India, about 33% of the daily gas demand can be stored and consumed during one of normally three cooking times. The HRT should be increased at a low digestibility and at low ambient temperatures. This is done in India where digesters of 30, 40, and 55 days HRT for the same gas production are being installed.

In China, the construction of family-sized fixed-dome digesters is advanced and already standardized at national level (14). In Nepal, construction is standardized as well because there is only one agency, the Biogas Company, involved in this business (19, 24). In India, a governmentally approved design (Janata plant) (25) is still under development and needs further modifications. In Thailand, many agencies have developed their own designs independently from each other and the National Energy Administration (NEA) recommends its design.

There is definitely the need to improve digester design to reduce construction costs, to minimize surface to volume ratio and improve the statics. The Asian Institute of Technology (AIT) is going to conduct more in-depth research with CAD (computer aided design) to determine the statistical stability and optimize design. In the following section, some designs and construction techniques are described in more detail:

China

China has developed three standarized designs of fixed-dome digesters which are already accepted in many provinces: a) a cylindrical type, b) a spherical type, and c) an elliptical type (14). Designs under b) and c) are newly developed. There are modifications in the location and shape of inlet and outlet containers. The digesters can be made of bricks, of concrete (cast in place) or combined concrete and bricks.

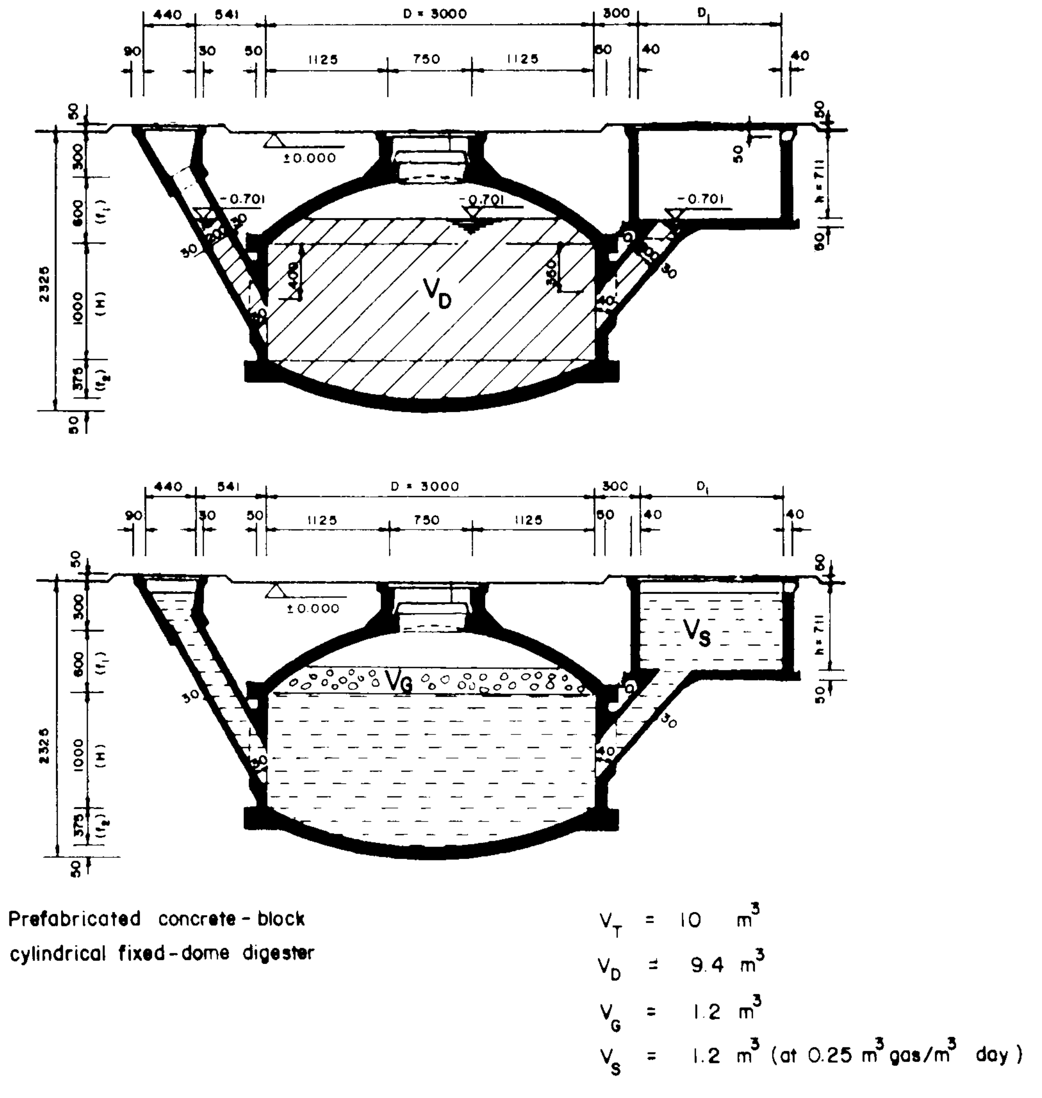
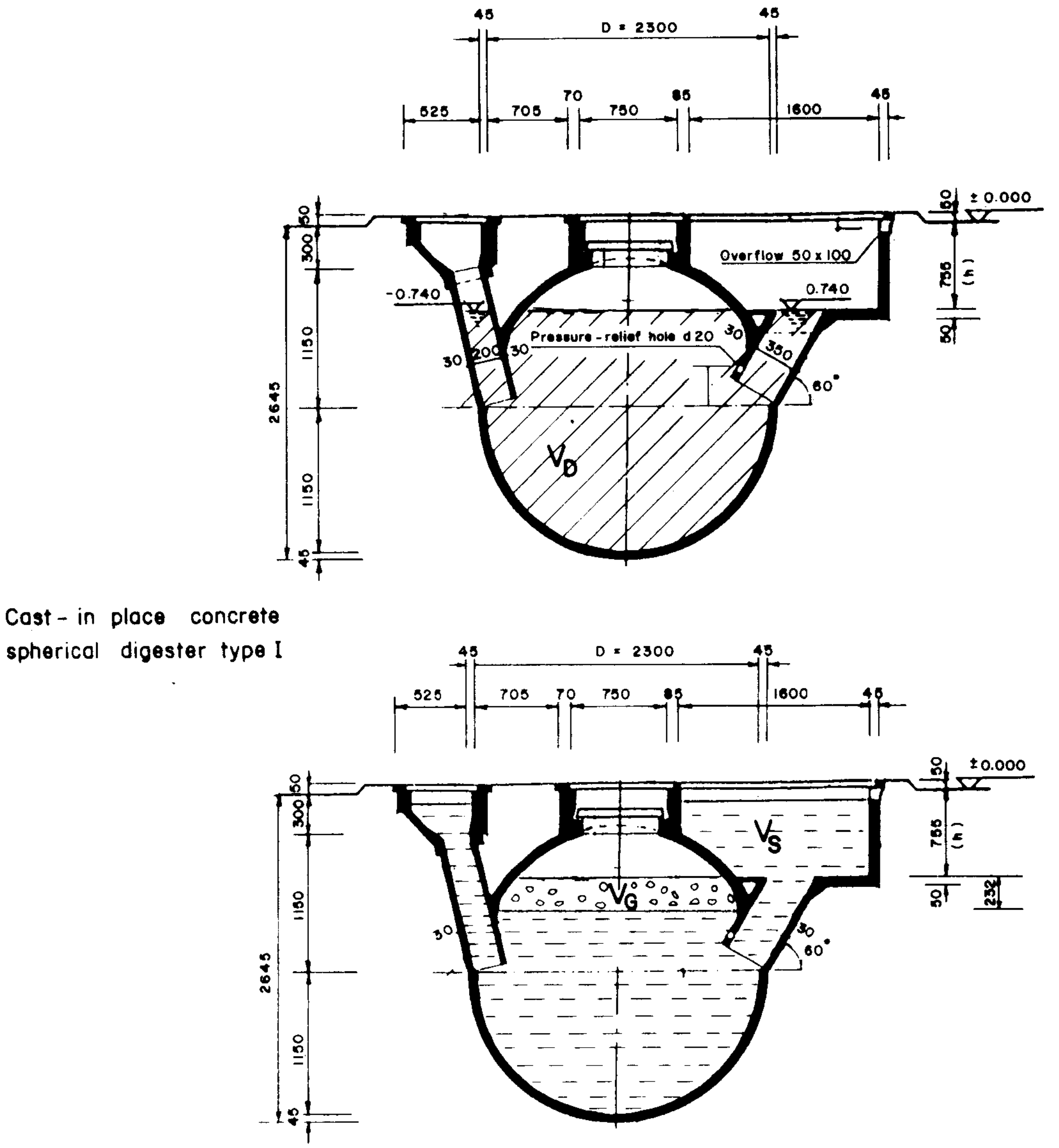


Figure 1: Prefabricated concrete-block cylindrical fixed-dome digester (adapted from 14)



$V_T = 6\ m^3$

$V_D = 5.4\ m^3$

$V_G = 0.7\ m^3$

$V_S = 0.7\ m^3$ (at $0.25\ m^3$ gas / $m^3 \cdot d$)

Figure 2: Cast-in-place spherical digester Type I (adapted from 14)

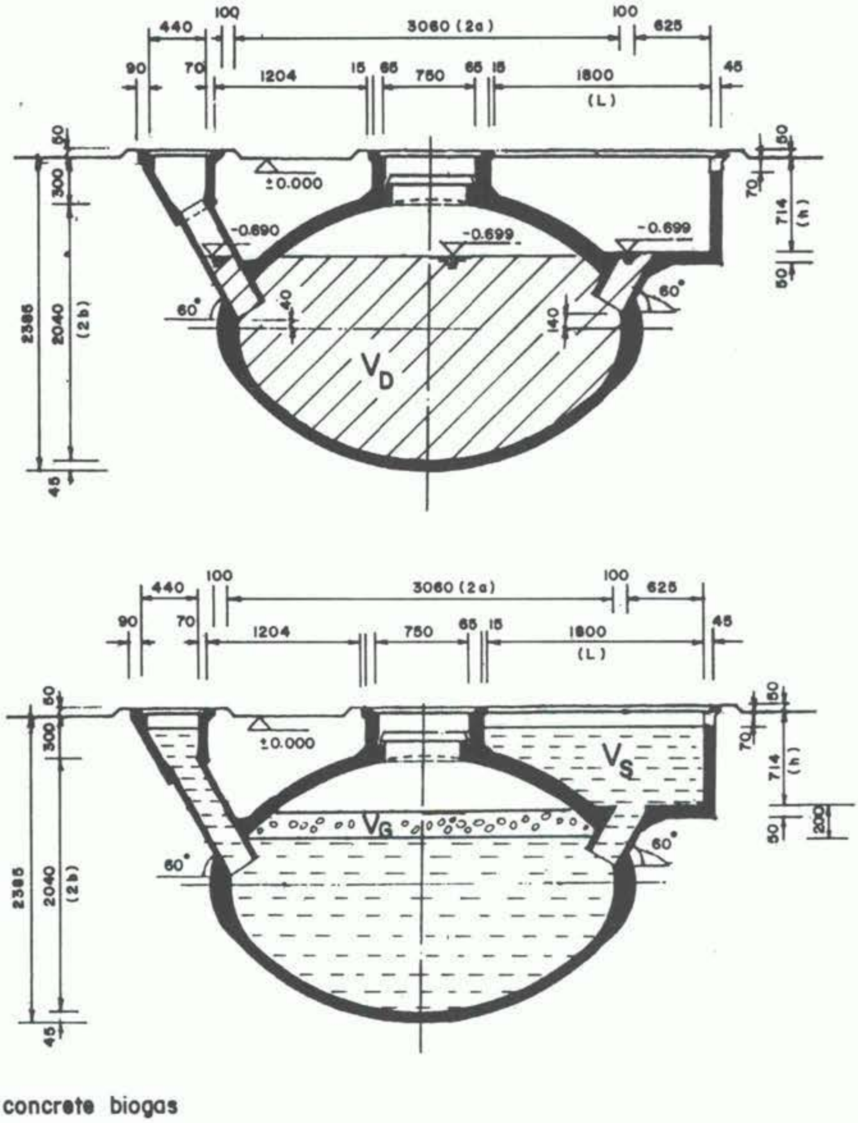
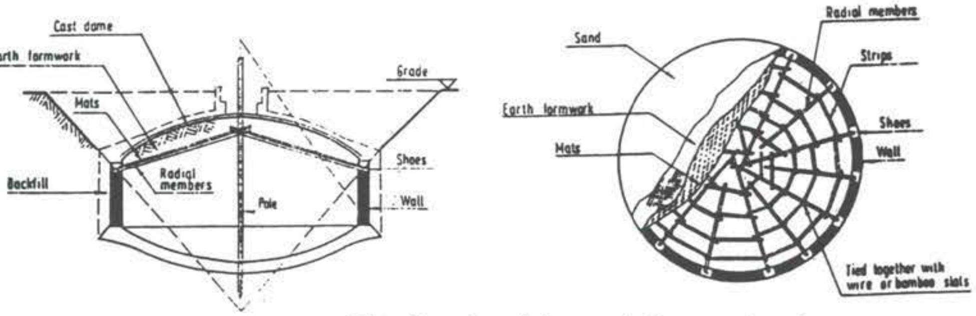


Figure 3: Cast-in-place concrete biogas digester of elliptical type A-I (adapted from 14)

There are many modes of construction of the cylindrical type. The technique for cast dome on an umbrella-shaped formwork is shown in Figure 4. In case the whole digester is being cast-in-place, it could be done as Figure 5 demonstrates.



Umbrella-shaped formwork for casting dome

Figure 4: Construction technique for cast dome on umbrella-shaped formwork (adapted from 15).

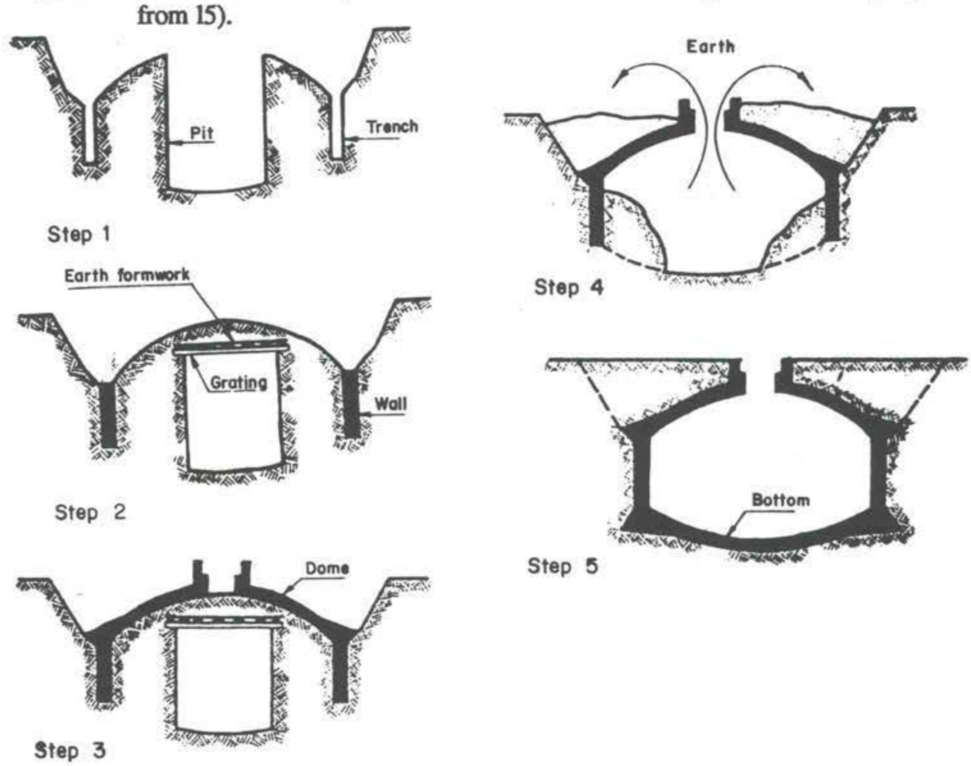


Figure 5: Construction technique for concrete cast-in-place digester (adapted from 15)

The latter construction technique has the advantage that no formwork and no back fills are necessary as the cylindrical part (i.e., the wall) is in direct contact with undisturbed soil. The digging process has to be done very carefully to achieve vertical walls. Sandy soils are not suitable. In this technique, cylinder and dome are one part without joints. These are only at the bottom. The umbrella-technique allows casting the dome on brick masonry or on concrete walls, but there is a joint. This may lead to cracks and gas leakages.

Digesters may also be cast by using molds. The bottom is cast first, then the cylindrical part and finally the dome. Another possibility is to use precast concrete blocks as shown in Figure 6.

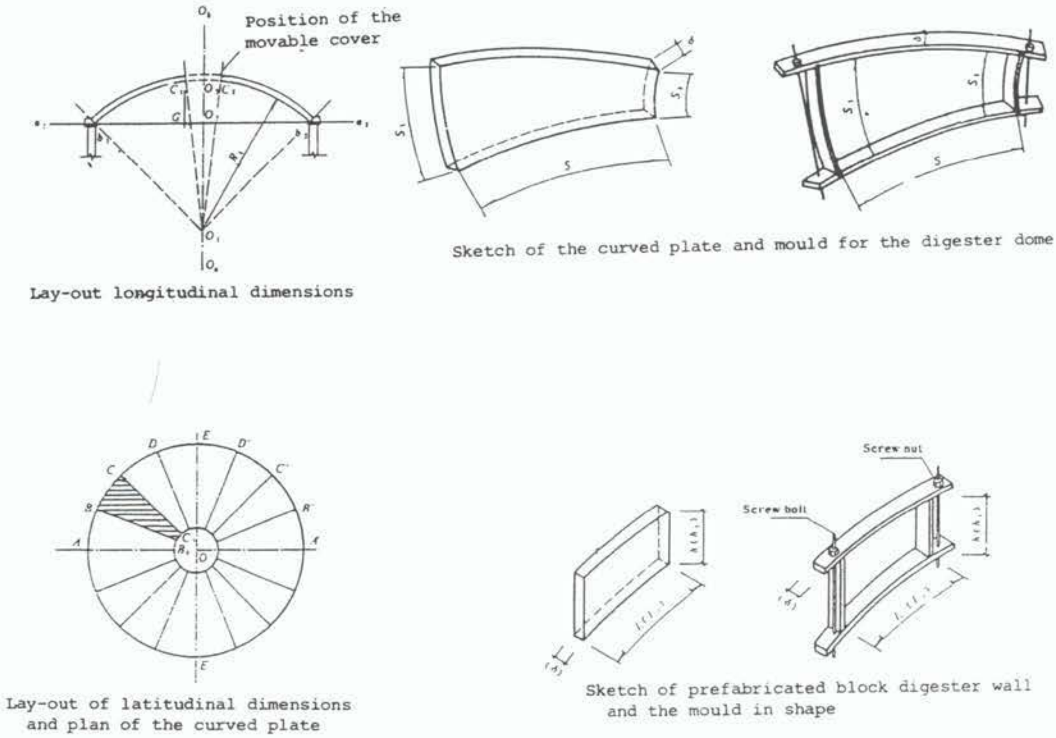


Figure 6: Molds for digester wall and dome, layout of latitudinal dimensions (14).

The digesters are designed for 4, 6, 8 and 10 m^3 total volume.

There are altogether four kinds of building materials adopted for digester wall and dome:

1) cast-in-place concrete;

2) prefabricated concrete blocks;

3) standard bricks; and

4) block stones.

The bottom is always cast in place. Different material may be combined to construct wall, dome and outlet chamber. There are two kinds of inlet and outlet pipes, a round pipe and a pipe square on the outside and round inside.

The cost breakdown of a 6 m^3 cast-in-place cylindrical fixed-dome digester is given in Table 7.

Table 7: Cost breakdown of a 6 m^3 fixed-dome digester

Material	Amount	Unit Cost	Total Cost (Yuan)	Total Cost (%)
Steel	10 Kg	1100 Yuan/t	10	3.9
Cement	600 Kg	100 Yuan/t	60	
Sand	1.5 m^3	20 Yuan/m^3	30	11.8
Gravel	1.5 m^3	20 Yuan/m^3	30	11.8
Bricks	500	0.25 Yuan/piece	125	49.0
			255	100.0

Source : Biogas Research and Training Centre, Chengdu. 1US$ = 3.69 Yuan (July 1986).

Operation

The digesters are normally operated for 8-10 months a year. The gas pressure in fixed-dome digesters is equal to or below 120 cm WC. The HRT both for cow and pig manure is 35-40 days at TS concentrations of 5-8% and 4-7%, respectively. Gas production varies between 0.15-0.6 m^3 digester volume per day and will depend on the ambient temperature. In Southern China, the average gas yield of a family-sized digester is 280-300 m^3 per year, in Northern China 150-210 m^3 per year (15, 31).

The digesters are usually discharged twice a year and filled again with about 100 kg of composted straw or maize stalks per square metre of digester volume. Manure and night soil are added daily.

India

India's "National Project on Biogas Development" (NPBD) for mass diffusion of digesters follows a "multi-agency, multi-model" approach. The nodal agency, the Department of Non-Conventional Energy Sources (NDES), approved 4 designs (5):

A. The floating-drum type, commonly called the KVIC type.

B. The PRAD fixed-dome type, commonly called the Janata type.

C. KVIC type plant having digester made of angle iron and polyethylene sheets, called the Ganesh model.

D. KVIC type plant having digesters made of pre-fabricated ferrocement segments.

Digester types under A and B are mainly being disseminated for families, communities (CBD) and institutions (IBD).

The KVIC design was built in India from the very beginning of the development of biogas. It has received a few modifications only.

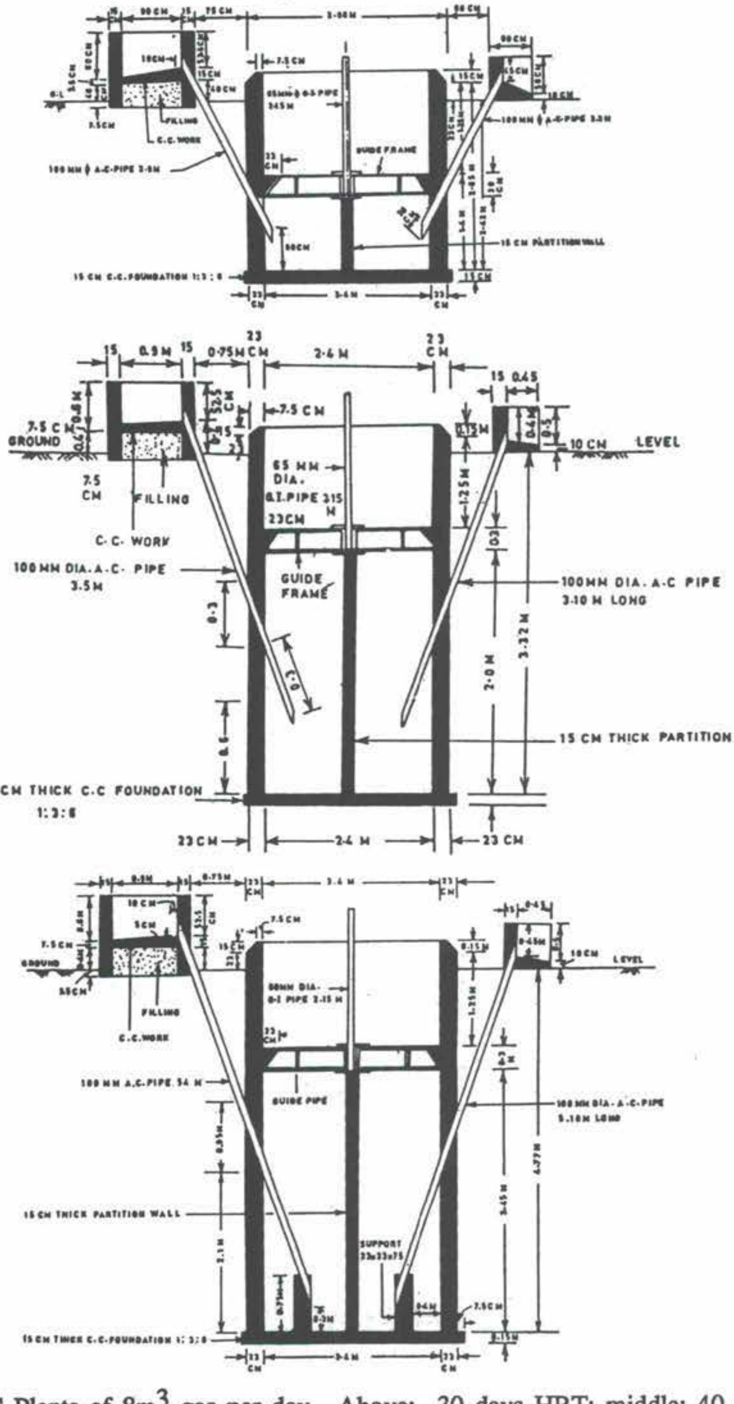


Figure 7: KVIC Plants of $8m^3$ gas per day. Above: 30 days HRT; middle: 40 days HRT, below: 55 days HRT (adapted from 5).

The latest modification is that the floating-drum is made of fibre-reinforced plastic (FRP) and not steel sheet any more. Figure 7 gives the cross sections of a digester producing 8 m^3 gas per day at HRT of 30, 40 and 55 days. The walls are made of bricks and are 23 cm thick.

These digesters are much easier to construct than the fixed-dome digesters and it does not matter if the walls develop hairline cracks. Construction of the digester by the farmer himself is possible. Nevertheless, special care must be taken in selecting the bricks (they have to be well burned), in laying and fixing inlet and outlet pipes, and in fixing the central guide frame. Digesters constructed in black cotton soil, which shrinks in the dry season, receive a back fill of 30 cm sand.

The material required for construction of the digester (exluding the floating-drum) is presented in Table 8.

Cost of the mild steel gasholder is about 50% of the total cost. It is now going to be replaced by FRP, which is 5% to 10% (or even more) higher in cost but is corrosion free if properly made and, thus, is maintenance free.

Janata biogas plant

This type of fixed-dome design is about 30% cheaper than the KVIC type of the same volume and is going to be more widely disseminated [Janata means people]. A cross section is given in Fig. 8. The walls are made of bricks and are 11.5 cm to 23 cm thick.

This design has almost no similarity with the above mentioned Chinese design. It is completely made out of bricks and the dome is constructed according to the umbrella-technique. But here, bricks (which have to be of good quality) are laid on the mold. Some space has to be maintained between each brick. This will be filled by pouring portland cement slurry into them.

Construction materials required for Janata plants are listed in Table 9.

Janata plants use less material than KVIC plants and a higher percentage may be produced locally from which local craftsmen can get additional income. Discussions are on-going to change and further optimize the Janata design. Designs from the People's Republic of China are under consideration for adoption.

A comparison of construction costs between the KVIC and Janata designs is presented in Table 10. The installation costs of Janata type are more than 30% cheaper.

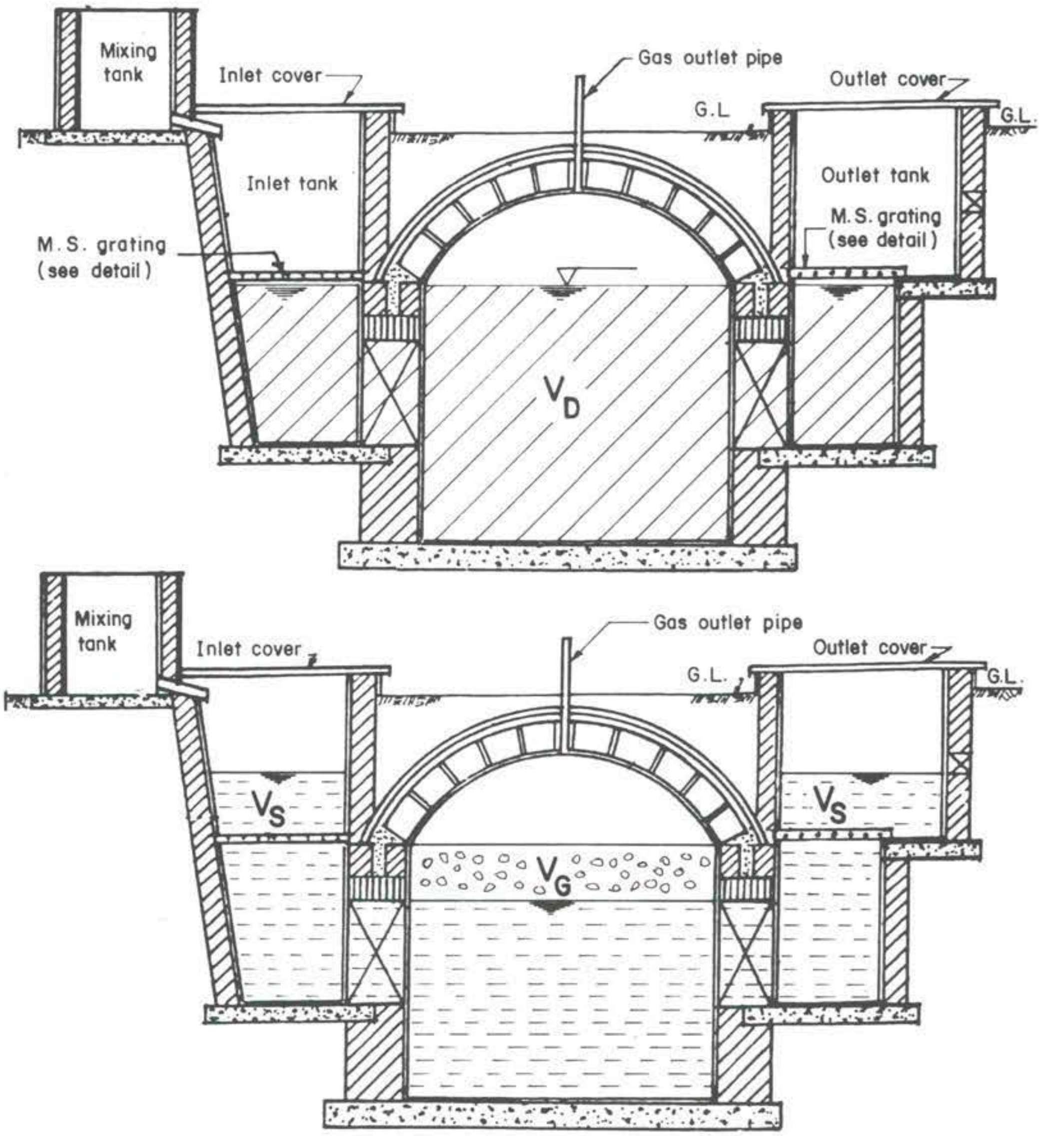
Operation

In India, digesters are operated almost exclusively with cow manure, called gobar, and are loaded once a day. Table 11 presents loading and gas production characteristics of digesters at a HRT of about 55 days. Specific gas productions (design criteria) for both KVIC and Janata types are 0.32-0.34 m^3 gas per m^3 digester volume per day and 0.20 m^3 gas per Kg TS in cow manure. These figures vary with HRT. Oversized Janata plants cause operational problems. The slurry is not discharged daily, because the volume of the hydraulic chamber/outlet tank is bigger than the volume fed per day. The gas storage volume is larger than the gas volumes produced per day. Thus, the gas is unable to displace enough liquid to get an overflow and the slurry level rises. This may lead to clogging of the gas pipe.

Table 8. Materials required for construction of different sizes (m^3 gas per day) of floating drum digesters

Size of plant (m^3/day)	2			3			4			6			8		
ret. time (d)	30	40	55	30	40	55	30	40	55	30	40	55	30	40	55
Material															
No. of bricks	2060	2460	-	2270	2770	-	2510	3210	4350	2900	3730	5100	3410	4430	6000
sand (m^3)	1.71	1.97	-	2.2	2.52	-	2.41	3.90	3.6	2.85	3.46	4.30	3.32	4.05	5.0
Stone chips (m^3)	0.60	0.60	-	0.85	0.85	-	0.95	0.95	0.95	1.25	1.25	1.25	1.40	1.40	1.40
Cement (bags)	11	13	-	15	17	-	16	19	23	19	23	28	22	26	33
A.C.pipe (100mmø)	3.4	3.8	-	3.6	3.6	-	4.9	6.3	9.5	5.25	6.5	10	6.6	6.6	10.5

Source: compiled from (19)



V_T = 8 m^3

V_D = 6.3 m^3

V_G = 0.7 m^3

V_S = 0.7 m^3

Figure 8: Design of a Janata plant of $8m^3$ total digester volume adapted from (25)

Table 9: Construction materials required for Janata plant

Size of plant (m^3 gas/day)	1		2		3	4	6	8	10
Retention time (d)	55	30	40	55			55		
No. of bricks	1000	1200	1400	1500	2500	3500	4000	5500	7000
Cement (bags)	15	16	18	20	25	30	40	60	70
Stone chips (m^3)	1.0	0.75	0.90	1.00	1.15	1.45	2.00	4.29	5.00
Fine sand (m^3)	2.0	1.70	2.00	2.00	2.30	3.60	4.30	5.70	6.45
Coarse sand (m^3)	0.75	0.75	0.90	0.90	1.15	1.45	1.70	2.90	4.30
Black enamel paint (liters)	1.0	1.0	1.5	1.5	2.0	2.5	3.0	3.5	4.0
A.C. pipe 6 " ø	-	2.75	2.75	-	-	-	-	-	-
G.I. pipe $^1/_2$" or $^3/_4$" ø (m)	25	25	25	25	25	25	25	25	25
Cement concrete covers (pieces)	one	one	one	two	two	two	two	two	two
Gas distribution line	should be determined by each beneficiary								

Source: (compiled from 5, 25)

Table 10: Comparison of installation cost between KVIC and Janata plants as at March 1983

Size m^3 gas/day	KVIC Plant						Janata Plant								
	40 days HRT 1)			30 days HRT 1)			50-55 days HRT 1)			40 days HRT 1)			30 days HRT 1)		
	m^3*	Rs	Rs/m^3	m^3*	Rs	Rs/m^3	m^3*	Rs	Rs/m^3	m^3*	Rs	Rs/m^3	m^3*	Rs	Rs/m^3
1	-	-	-	-	-	-	3.00	2200	733	2.18	1980	908	1.64	1760	1073
2	3.86	4480	1161	2.86	3870	1353	5.92	3800	642	4.30	3420	795	3.22	3040	944
3	5.83	5440	933	4.32	4730	1095	9.15	4200	459	6.65	3780	568	4.99	3360	673
4	7.12	6190	869	5.85	5240	896	12.12	5200	429	8.81	4680	531	6.61	4160	629
6	11.02	7530	683	8.74	6400	732	18.60	6400	344	13.53	5760	460	10.14	5120	505
8	14.70	8940	608	11.31	7560	663	24.78	8200	331	18.02	7380	409	13.52	6560	485
10	18.41	10600	576	14.55	9100	625	30.47	10000	328	22.18	9000	406	16.62	8000	481
15	27.60	15800	572	20.70	13200	638	46.00	14500	315	33.45	13050	390	25.09	11600	462
20	36.82	12300	578	29.00	17600	607	60.90	18000	295	44.29	16200	366	33.22	14000	433
25	45.80	23500	513	36.30	20200	556	76.00	21250	280	55.72	19125	343	41.45	17000	410
30	-	-	-	-	-	-	51.50	24000	262	66.54	21600	325	49.90	19200	385

1 US$ = 12 Rs. (May 1986)
1) HRT = Hydraulic Retention Time
*) m^3 Digester Volume

Source: compiled and adapted from (25)

Table II: Loading and production characteristics of 2, 3, 4 and 6 m^3 gas per day Janata plants.

Gas production	Daily fresh dung	Volume of digestion chamber	Retention time, nominal	Specific gas production	
m^3 per day	Kg	m^3	days	m^3/m day	m^3/Kg TS.d
2	50	5.92	59	0.34	0.20
3	75	9.15	61	0.33	0.20
4	100	12.12	61	0.33	0.20
6	150	18.60	62	0.32	0.20

Source : (compiled and adapted from (25)

Digesters operated with cow manure which was well mixed with water do not develop floating layers. Thus, annual cleaning is not required.

Nepal

The construction of fixed-dome digesters started in 1980 and accounts now for 93% of all installations. A local design was developed and is being disseminated by one agency, the Gobar Gas Company, with the authorization of ADBN (Agricultural Development Bank Nepal). The cross section is given in Figure 9.

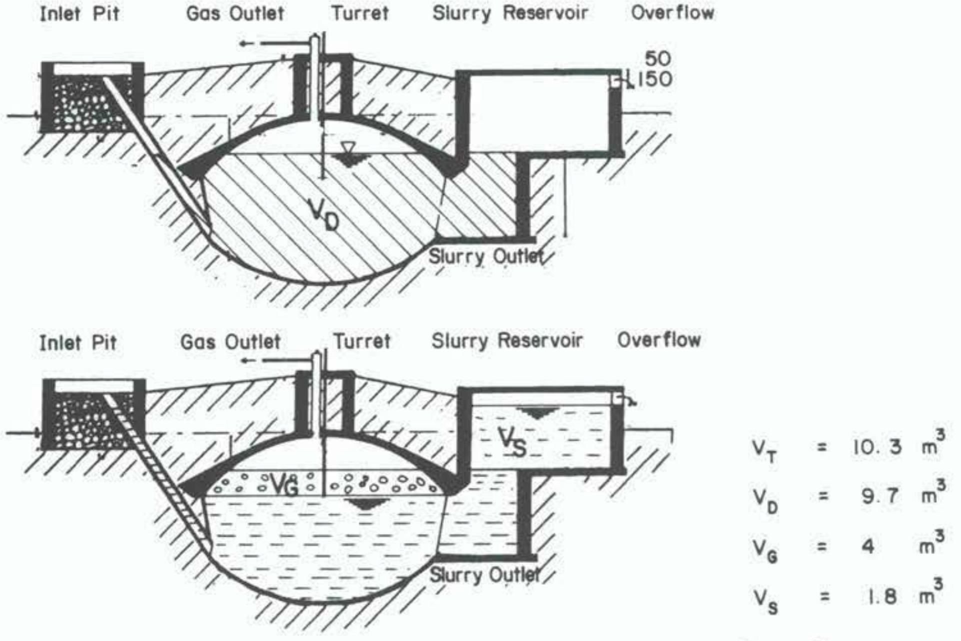


Figure 9: Design of Nepalese Fixed-dome digester, (adapted from 19)

The construction technique is similar to the one given in Fig. 5 but the dome is cast first. This is shown in Fig. 10. The digester shape is normally dug into the undisturbed ground and receives a plaster of 3 cm thickness only. The dome serves for gas storage. The walls of the outlet and inlet containers are made of bricks.

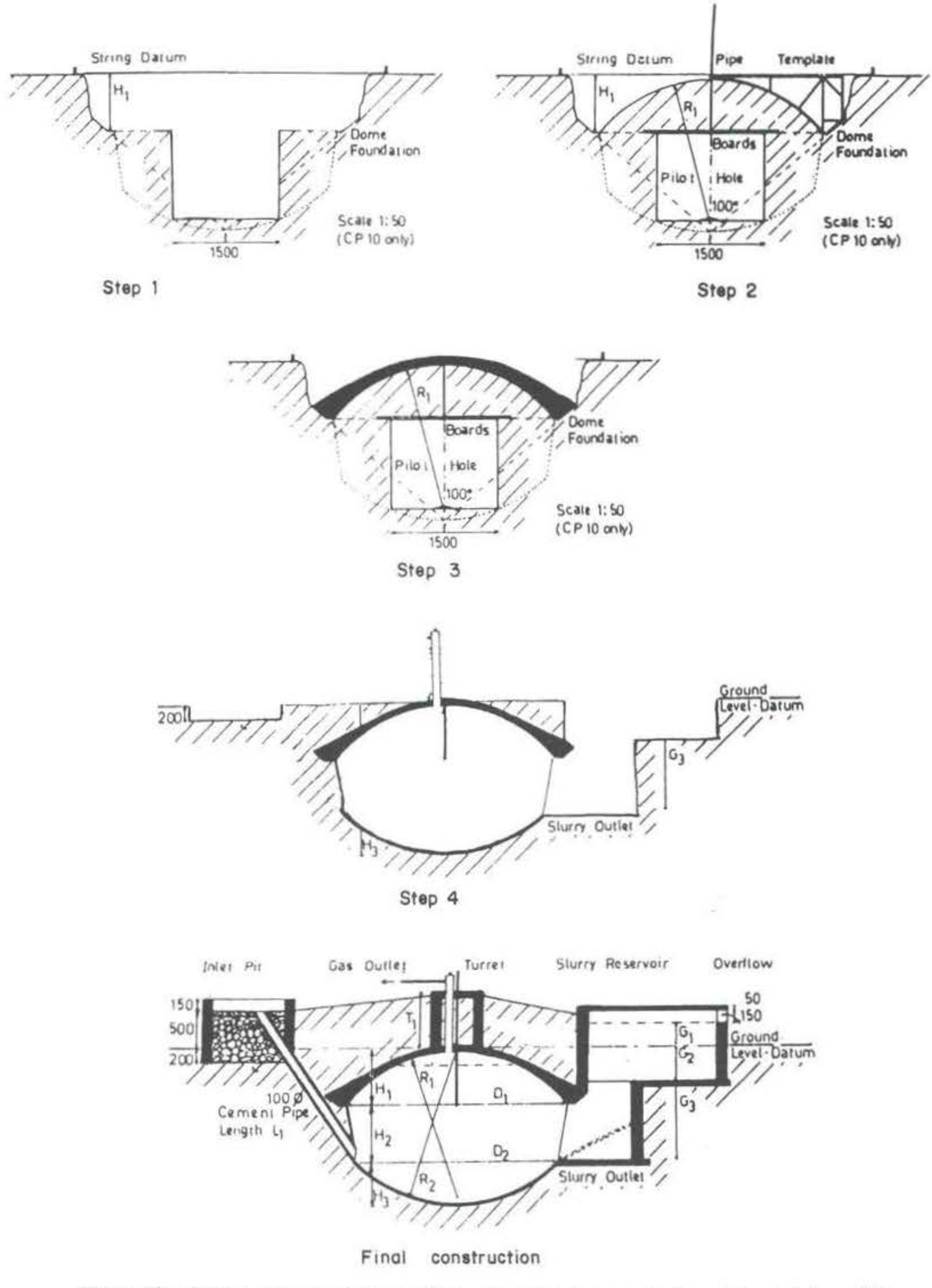


Figure 10: Construction technique of Nepalese fixed-dome design, (adapted from 19).

A breakdown of construction costs is given in Table 12. The table is divided into two parts, i.e.materials supplied by Biogas Company and by the farmer.

Table 12: Breakdown of construction cost of different sizes (m^3 digester volume) of fixed-dome digesters (in Rs.)

Size (m^3) digester volume)	10		15		20		50	
	Rs.	%	Rs.	%	Rs.	%	Rs.	%
Material supplied by Biogas Co.	8073	53.3	10054	50.9	12364	49.5	21058	43.0
Construction charge 1)	2800		3800		4600		9200	
Guarantee charge 2	1000		1500		2400		5500	
Sub-total	11873	78.5	15354	77.7	19364	77.5	35758	73.1
Supplied by farmer:								
Bricks	720		900		1200		4800	
Sand	600		672		750		1800	
Gravel	320		480		560		1600	
Labour	1250		1875		2500		3750	
Transport	360		480		600		1200	
Sub-total	3250	21.5	4407	22.3	5610	22.5	13150	26.9
TOTAL	15123	100	19761	100	24974	100	48908	100

Source: (adapted from 26); 1US$ = 21 Nepalese Rs. (April 1986)

Nepal is a land locked country and has to import almost all metal parts. Thus, specific costs are high. There is the chance to reduce installation costs by 10-20% by further optimization.

Operation:

Like the case in India, the digesters are loaded with cow manure. Loading characteristics, which are design criteria as well, are presented in Table 13. The specific gas production per kg TS in cow manure is slightly higher than in India.

Table 13: Loading characteristics for fixed-dome and floating-drum digesters.

No	Capacity (m3 digester volume)	Type	No of family members	No. of animals needed	Manure (Kg/day)	Gas production			Retention time
						m3/d	m3/m3.d	l gas Kg.TS	(d)
1	6	dome	4-6	3-4	36	1.84	0.31	255	83
2	10	dome	4-9	4-6	60	2.97	0.30	247	83
3	15	dome	9-12	6-9	90	4.67	0.31	259	83
4	20	dome	12-18	8-12	120	6.37	0.32	265	83
5	35	dome	21-25	14-21	210	11.04	0.31	263	83
6	50	dome	30-45	20-30	300	14.86	0.30	248	83
7	34	drum	30-45	20-30	300	14.16	0.42	236	56.7
8	51	drum	45-65	30-45	450	21.24	0.42	236	56.7
9	68	drum	60-90	40-60	600	28.32	0.42	236	56.7

Source: (adapted from 24)

Thailand

Fixed-dome digesters are being constructed almost exclusively since 1980. There are three different designs in Thailand. The design of the Sanitation Division (SD) of the Ministry of Public Health (MPH) has received not less than 12 modifications by various construction teams. The main features of the three designs are presented in figures 1, 2, and 3. The dome of the SD design is not covered with soil which may easily lead to cracks. The unbalanced volumes (V_G, V_S, V_D) cause problems during operation. This design should not be used any more.

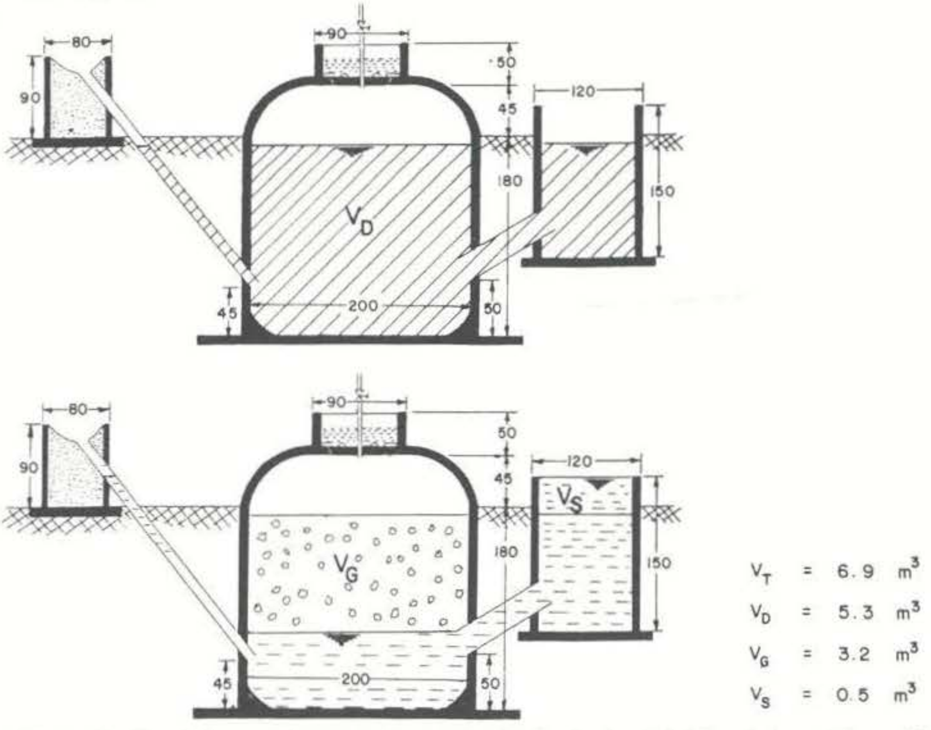
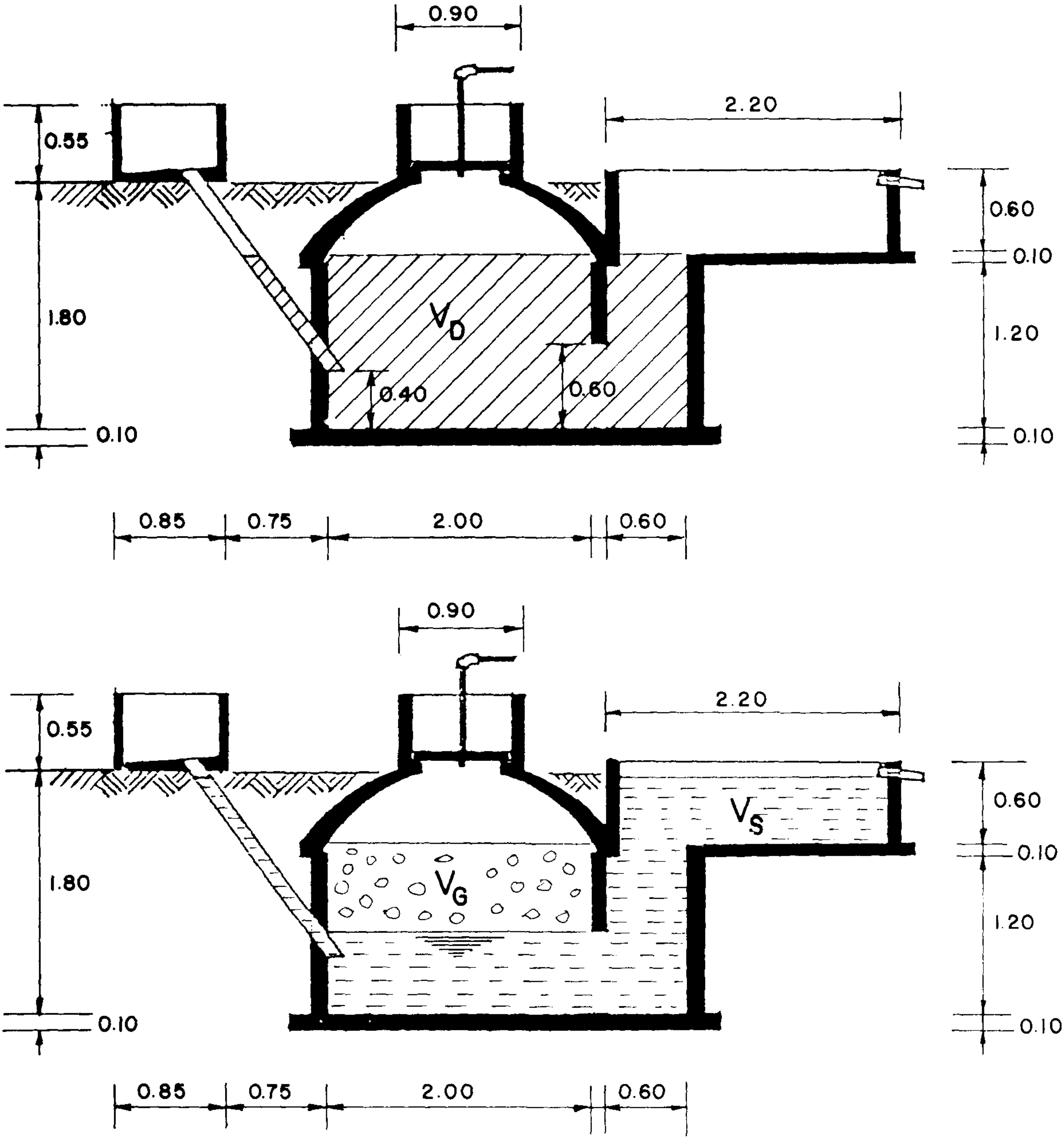


Figure 11: Fixed-dome digester designed by the Sanitation Division (adapted from 20)



V_T = 5.1 m^3

V_D = 4.1 m^3

V_G = 1.9 m^3

V_S = 1.9 m^3

Figure 12: Fixed-dome digester designed by the National Energy Administration (NEA) (adapted from 5)

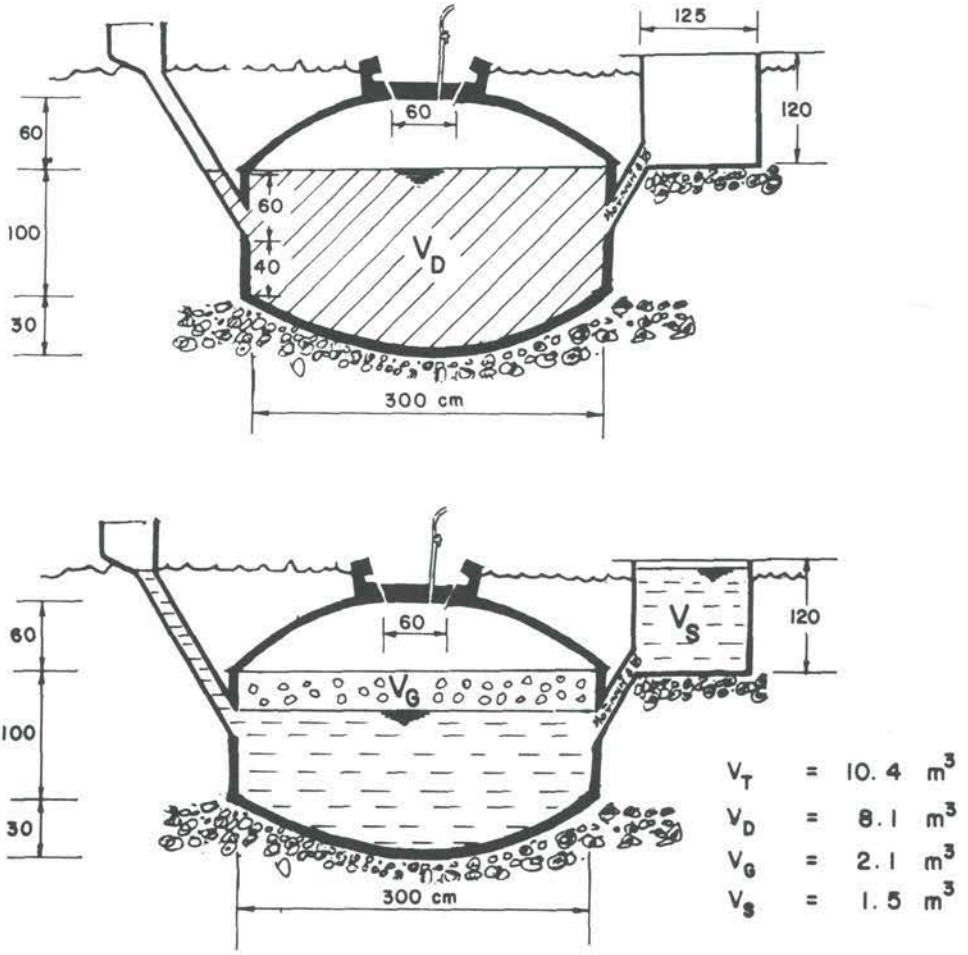


Figure 13: Fixed-dome digester designed by Department of Agricultural Extension (DOAE) (adapted from 20)

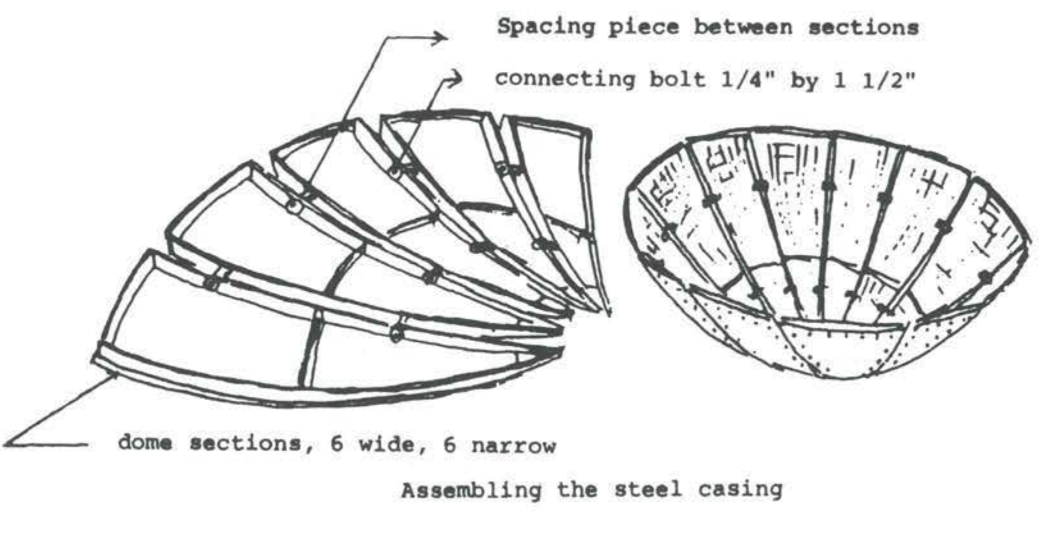


Figure 14: Assembling the steel molds for the dome (34).

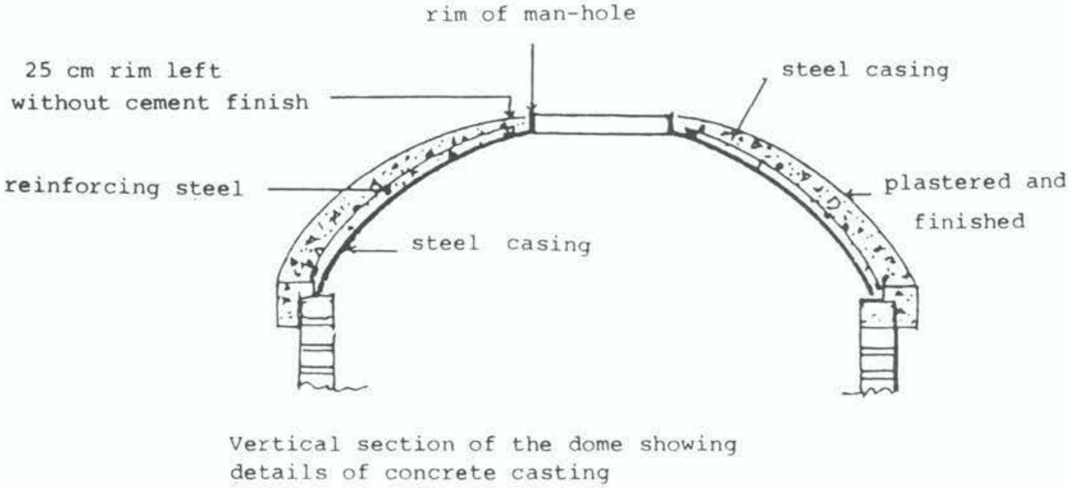


Figure 15: Finished cast-in-place dome (34)

The National Energy Administration (NEA) recommends cast-in-place construction and is providing steel molds for the walls and the dome free of charge to the farmers. Transport to the site is expensive due to the high weight. Figure 14 shows how the steel molds are being assembled and Fig. 15 shows how the dome sits on a cylindrical wall made out of bricks. This technique may easily lead to cracks and hence to gas leakages. In addition, the gas volume in the dome is unuseable. It is stored only in the cylindrical part, similar to the Janata type (see Fig. 8). Cracks at the joint between dome and wall will always leak because they are never sealed by the slurry. The design of the DOAE is similar to the actual Chinese design of cylindrical fixed-dome digester. Table 14 gives the cost breakdown of a 7 m^3 fixed-dome digester made of concrete.

Table 14: Cost breakdown of 7 m^3 fixed-dome digester, made of concrete (March 1985)

Materials	Cost			
	Baht*		%	
	near	remote	near	remote
Cement 23 bags, 1 bag = 72-75 Baht	1,656	1,725	36.3	32.7
Sand 3 m^3, 1 m^3 = 120-150 Baht	360	450	7.9	8.5
Gravel 3 m^3, 1 m^3 = 300-350 Baht	900	1,050	19.7	19.9
Construction steel, 20 pieces, 1 pc. (10 m) = 25-30 Baht	500	600	11.0	11.4
Cement pipe 6", 3 m	100	150	2.2	2.8
Cement pipe 8", 2x1 m, 1 m = 80-85 Baht	160	170	3.5	3.2
Steel wire 1 kg	20	20	4.4	3.8
Gas valve 2 pc., 1 pc. = 80 Baht	160	160	3.5	3.0
Rubber pipe 20-30 m, 1 m = 15 Baht	450	450	9.9	8.5
Burner 250-500 Baht	250	500	5.5	9.9
	4,556	5,275	100.0	100.0

* 1US$ ≠ 26 Baht

New design for family-sized digester

A new design, which can not be found in Asian countries yet, is of the Sasse type. This design avoids some disadvantages of the other types and is easy to construct. Figure 16 shows a comparison of this design (high pressure fixed-dome or low pressure floating-drum) to a conventional KVIC type digester.

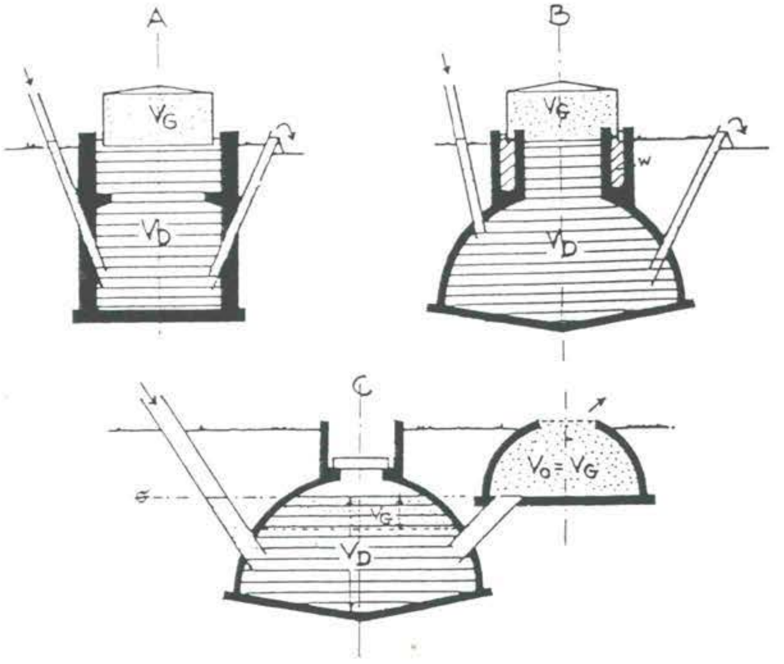


Figure 16: Comparison of Sasse-type family-sized digester with KVIC type (35)

There is only one point of discontinuity where the shell meets the bottom. The construction process of a plant built in Mauritania in 1986 is shown in Fig. 17. In this case, the cavity was dug into laterite soil which received a plaster only.

Usually, the masonry construction technique of the spherical shell is similar to the Chinese technique. Detailed instructions on design, construction, and operation are presented in (35). More attention should be paid to this digester type in national biogas programmes.

Experiences with biogas technology

China has learned many lessons during the recent past. Cheap but low quality biogas plants (20-30 Yuan) were constructed by the farmers themselves during 1975-79. In 1980, 53% of all digesters were defective. In consequence, construction activities were slowed down from 1.6 million to 0.5 million per year but digesters were of high quality and built by skilled masons. Ninety-five per cent of all digesters constructed since 1980 were flawless and 85% are in use. Local conditions are studied first before biogas plants are being introduced, because not all areas are suitable. It was learned that the popularization of BGT would only be successful, when the direct benefits to the farmers are obvious. Thus, biogas technicians help in comprehensive utilization of gas and residues. Family-sized biogas plants are considered mature technology and

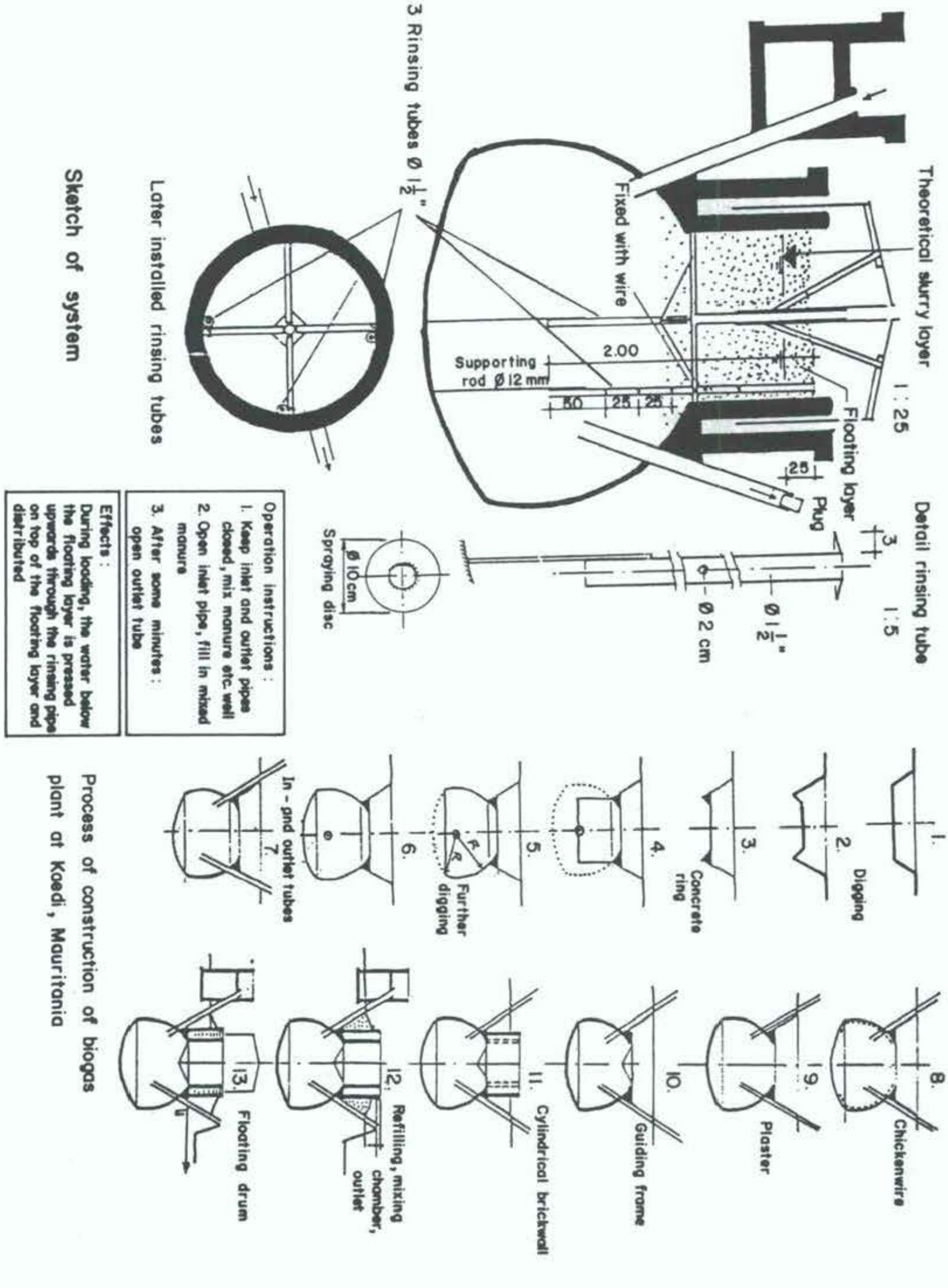
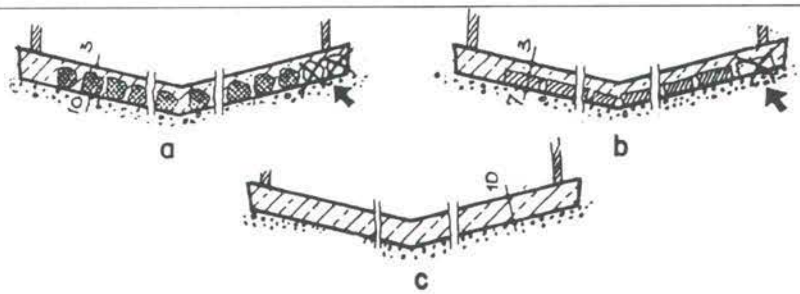
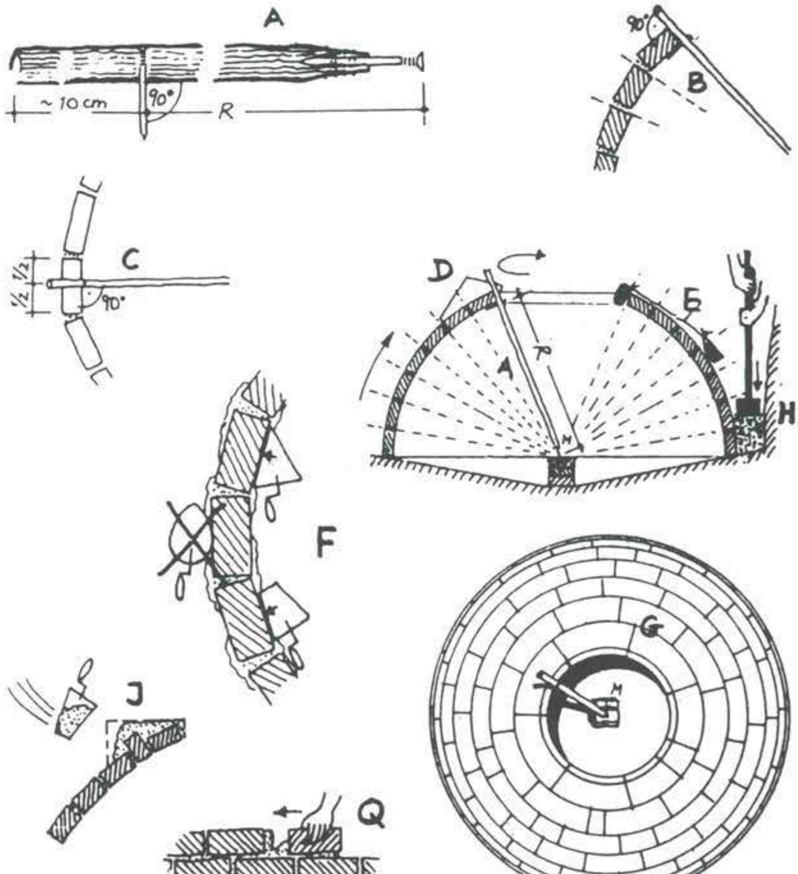


Figure 17: Construction of a low pressure digester of the Sasse type in laterite soil (36)



The bottom slab
A flat slab must be flexurally rigid if it is to distribute the edge loads over the entire surface. Possible forms of construction: Quarrystone with cement motar (a). Masonry with cement floor (b) and concrete (c). Underneath the wall the bottom slab should be made out of massive concrete.



Construction of a spherical shell from masonry.

Figure 18: Normal method of construction of bottom and shell (adapted from 35).

current interests in R & D focus on medium and large digesters for community use. People recognised that management is the key to success, because the development of BGT is a long term option. The current success of the Chinese biogas programme was made possible only through the strong support of the Chinese Government.

The experience in India was similar. Biogas activities gained momentum only after launching the "National Project on Biogas Development" (NPBD) in 1981 in selected Provinces and Districts, and establishing the DNES in 1982. The number of total installations could be almost doubled every year because the richer farmers now consider that they should have a biogas plant. The current success is due to strengthening the organizational structure and to various incentives for both farmers (e.g. subsidies, loans, repair charges) and agencies and turn key workers (cash incentives, service charges, turn key job fee, allowances for training courses). The subsidies to farmers are of a fixed amount and not any more a percentage of the total cost to reduce delays in payment. About 88% of all digesters constructed during NPBD are operating. Special problems occured with the construction of JANATA (fixed-dome) digesters. To overcome the problem of low skill, refresher courses were introduced for masons who already passed one course successfully. Benefit-cost ratios are low in India. Since most of the farmers tend to oversize the digester, this ratio is even getting lower than one. At a certain income level, status symbols seem to be more important than a high benefit-cost ratio. The farmers would also pay more for a guaranteed durability of civil construction and accessories.

In Nepal, the Biogas Company claims that 95% of the family-sized plants constructed by them, are still operating. The civil construction seems to be of good quality but of high cost because almost every metal part has to be imported. There may be the chance to reduce costs by 15% by optimizing digester geometry and construction techniques. His Majesty's Government of Nepal has fully recognised the biogas technology and will hopefully release funds to subsidize every digester by 25%. This is necessary to increase the demand for biogas plants which is stagnating. The Biogas Company is still working below full capacity and cannot yet reach its break-even point of 360 digesters per year.

In Thailand, overall experiences were negative. Fifty-six per cent of all digesters are being abandoned after one year of operation. After 4 years of construction, almost 90% of all digesters are left idle. This is obviously due to the fact that the farmers were not skilled enough and have to construct digesters on their own. Thus, the temptation is high to change the shape according to their own ideas and save cement wherever the farmers consider it possible. For example, plastering of the dome inside was dropped sometimes. Again, the designs developed by different agencies in Thailand cannot be considered optimized. Since no agency was reponsible for construction, no guarantee was given and after construction, service is almost non-existant. Under these conditions, a national family-sized biogas plant programme will fail and only a few highly committed farmers will stick to biogas. NEA is shifting the emphasis to larger scale systems of farms and industrial installations (livestock farms, slaughter houses, etc.).

In general, BGT is a modern (and not home-made) technology able to tackle environmental problems and conserve natural resources, keeping in mind that the annual wood deficit is 60 million tonnes in China, 84 million tonnes in India, 3 million cubic metres in Nepal and up to 30 million cubic metres in Thailand. The peasants have to develop a medium term perspective before or while investing in a digester, but the governments must take a long term perspective. This was done in China and India. Nepal has developed a 5-year programme. BGT has been placed at as high a priority as improved cooking stoves and reafforestation.

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GEOTHERMAL ENERGY—the gift of heat under the land of ice

by Jeffrey Cosser, *News From Iceland**

INTRODUCTION

Natural subterranean heat is one of Iceland's most striking features, and the country is a world leader in the application of geothermal energy, particularly for space heating. Since the beginning of human habitation this natural heat has been recognized as a special feature of Iceland. Norwegian and Icelandic saga literature make many references to hot pools and springs in different parts of the country and indeed Icelandic placenames often contain the elements:*reyk* ("smoke," but widely applied to rising steam), *laug* ("hot pool") and *hver* ("hot spring").

For many centuries, exploitation of geothermal energy was limited in scope and extent because the necessary technology did not exist. People used hot water for bathing, and a few farms had saunas built over hot springs or steam jets. Some cooking was done in the hot soil in spring areas, including the baking of a dense rye bread in later times. And of course spring water was used for washing clothes, as was done in Reykjavík in the springs whose steam gave rise to the placename, which means "bay of smokes." But until modern times, people had no way of increasing the flow of water, transferring it over distances or harnessing its energy in other forms.

The first steps in what might be called the scientific study of Iceland's heat resources were taken more out of general curiosity than with any proposed applications in mind.

In the 1750's the first boreholes in Iceland were drilled in what is now part of the city of Reykjavík and in Krísuvík, a geothermal area directly south of the city. This was carried out by Bjarni Pálsson and the poet and naturalist Eggert Olafsson, as part of a survey of the country and its natural resources commissioned by the Danish Academy of Sciences. When the boreholes had reached a depth of about eight metres, the springs started to spout.

Iceland's geothermal energy attracted the attention of many foreign visitors, including the German chemist Robert Bunsen, who in 1846 studied the spouting spring Geysir and advanced a theory of its mechanism which is still accepted, with only minor modifications, today.

Connected with Continental Drift

Iceland is the product of the process of continental drift. The North American and Eurasian continental plates are moving in opposite directions, and the resulting rift in the earth's crust is filled by extrusions of magma from deeper levels, forming the Mid Atlantic Ridge. Iceland was produced by this process, and straddles the ridge itself, the central section of the island being younger than the western and eastern edges, where the age of the oldest rocks has been estimated at about 15 million years.

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Measurements show that Iceland itself is being widened by the upwelling of magma by about 2 cm per year. Some of the magma penetrates through to the surface in volcanic eruptions, while in other areas it cools as intrusions within the crust.

Areas of geothermal activity can be divided into two classes: high-temperature areas and low-temperature areas.

High-temperature areas, located in the neovolcanic zone, the area of rifting and volcanism, contain sources of water at more than 150°C at a depth of 1 km. Precipitation water in these areas is heated by the magma intrusions that lie below, reaches great temperatures, and rises, often appearing at the surface in steam vents and fumaroles.

In the low-temperature areas, located far and wide outside the neovolcanic zone, the maximum temperature is 150°C. The water here is conveyed through rock fissures from more mountainous upland areas, and appears at the surface in the form of hot springs.

Exploitation of the energy in geothermal fields depends on the nature of the field: water from low-temperature areas can be used directly in district heating systems, while that from high-temperature areas contains too high a level of dissolved solids. If it were used, the dissolved chemicals would precipitate out in the distribution system and make a complete replacement necessary within a short time, so that instead, methods must be found of extracting heat from the water and using it to heat up comparatively pure cold water.

Surveys and site studies of geothermal potential now involve highly sophisticated techniques of measurement, analysis and data-processing, bringing together a number of specialized scientific disciplines. In the early days of the practical applications of geothermal energy in Iceland, only low-temperature fields were exploited, calling only for relatively straight-forward engineering procedures. With the growth of the urban population and the extension of district heating systems, deeper drillings became necessary and in more recent years attention has been turned to the exploitation of high-temperature fields, both as sources of heat and for electrical generation.

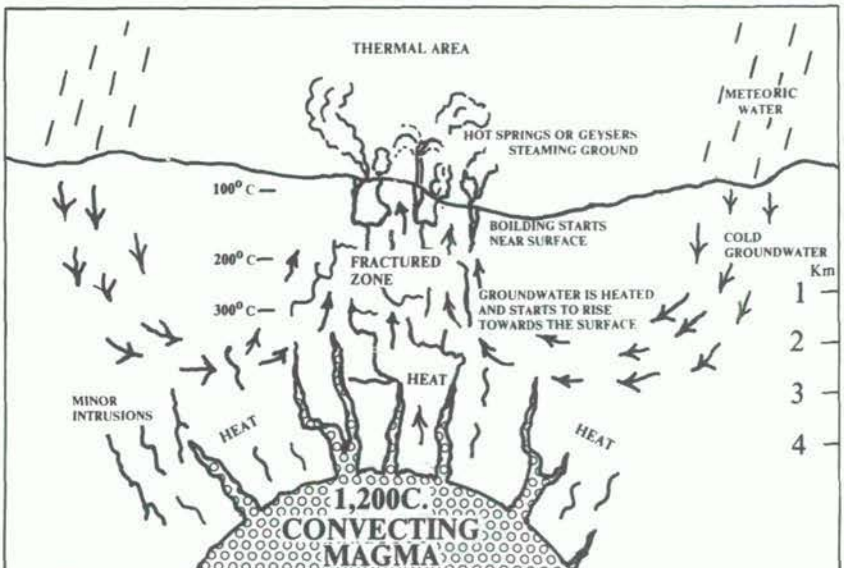

Figure 1. Model of a geothermal system showing the convection mechanism by which rising hot water is replenished by precipitation (the cycle can span hundreds of years).

Multi-discipline Research Needs

Deep drillings and the exploitation of high-temperature fields involve large expenditures of both money and effort, and they are not undertaken without extensive prior studies. Research on geothermal energy in Iceland is the responsibility of *Orkustofnun* (The National Energy Authority) which was established in 1967 to study energy resouces and act in an advisory capacity to the government in all matters concerning energy development in Iceland. Before the foundation of Orkustofnun, goethermal research was conducted within the State Electricity Authority.

Surface exploration brings together a number of disciplines in order to locate potential energy sources and decide where exploratory and productive boreholes should best be sunk. Geologists make detailed maps of faults, fissures and the temperatures of any surface manifestations of the heat that lies below.

Geophysicists contribute information on the extent of thermal fluid in the ground gathered by various methods, including electrical resistivity tests: resistivity of the ground is closely related to the structural pattern of the rock layers as well as the quantity and temperature of water they contain, as revealed by distortions in the conductivity pattern (Schlumberger soundings) or the pattern of natural or induced magnetic fields (magnetotelluric soundings). Head-on-profiling, an extension of resistivity measurements first used in China and involving the integration of several profiles of the same region, has been perfected in Iceland as a method of locating geothermal aquifers formed by faults.

Chemical geothermometers are natural indicators of the geothermal levels in the form of chemicals contained in hot spring water and steam and gas emanations from fumaroles. The levels and proportions of dissolved substances in samples can be read by geochemists as indications of the temperature at depth.

To date, over 2,000 hot-water boreholes have been drilled in Iceland with a combined depth of about 500km. Boreholes range from 200 m to 2,500 m in depth, depending on the nature of the field. Set beside the depth of the first borehole, eight metres, these figures illustrate perhaps as well as any the technological gulf that separates the mid-eighteenth century from the present, and the scale of geothermal exploration and development in Iceland.

Economy, Cleanliness and Convenient Warmth

If conversion to electricity is brought into the picture, Iceland's geothermal potential represents, at least theoretically, a source which could easily supply all the power needs of the modern country.

The gross hydropower capacity in Iceland is estimated at 187,000 GWh/year, of which 64,000 GWh/yr are technically harnessable, and 40-50,000 GWh/yr are regarded as economically feasible. About 10% of this last figure, or 4,000 GWh/yr, have already been harnessed.

By contrast, the accessible geothermal resource base (at depths of less than 3 km) is estimated at 2.78×10^{10}GWh, and of this figure 9.7×10^{8}GWh are thought to be recoverable through boreholes. So far only 9,000 GWh have been utilized, representing less than one-thousandth of 1% of the recoverable potential, and yet geothermal energy accounts for almost one-third of all the energy consumed in Iceland.

Siting and economic considerations place a limit to the actual role of geothermal energy in the national power system. Geothermal energy is a highly economic source of heat for certain temperature requirements, but it is difficult to transport it over large distances. High-temperature fields represent a cheap primary source of electricity, with low investment costs. But where large amounts of power are needed for a known market, hydropower is seen as a more attractive alternative.

For these reasons, the main application of geothermal energy in Iceland to date has been in space heating, where about 70% of the energy derived from boreholes is currently utilized.

First Developments

The first Icelandic experiments in space heating with geothermal energy date from the early part of this century, when a few homemade systems were set up on individual farms in the years 1908-1924, mainly in the west and southwest of the country. The period 1924-30 saw the building of a hospital and a number of boarding schools in various parts of the country at sites with available geothermal heat, exploiting it for space heating and swimming pools.

The first urban district heating system was developed, appropriately enough in Reykjavík,whose name bears witness to its most striking attribute in former times: the presence of natural steam. Today the steam is no longer to be seen, having long since been chanelled into the city's heating system, thus making Reykjavík a smokeless capital.

In 1928, drilling near the hot springs in the east of the city yielded 14 l/s (litres per second) of water at 87°C. Fourteen boreholes, the deepest 400 m deep, were sunk, using a drill which had been bought and used in an unsuccessful search for gold a few years previously.

In 1930 a distribution system was built, supplying hot water to the city's newly-built indoor swimming-pool, the National Hospital and about 70 houses. In 1933, the city authorities bought drilling rights in Mosfellssveit, 15 km northeast of Reykjavík, where sufficient hot water was found to plan a heating system for the whole city of Reykjavík as it then was. Development of the site and installation of space heating systems were delayed by the outbreak of war, but in the autumn of 1943 the Reykjavík District Heating System went into commission, with a supply of 200 l/s and serving 2,300 houses.

The war years and the following decade saw the greatest demographic social changes in Iceland's history with the phenomenal growth of Reykjavík, so the system's capacity was soon rendered inadequate in terms of the expanding requirements.

Improved methods of scientific exploration revealed the existence of large reserves of hot water within the city area which were developed during the 1950's and 1960's. Subsequent re-development through deep drillings in Mosfellssveit and nearby areas led to a large increase in the hot water yield, with the result that three other municipalities in the capital area, Kópavogur, Gardabaer and Hafnarfjördur, made agreements with the Reykjavík system and the service was extended to them in the years 1973-76.

The present supply sources for the Reykjavík District Heating System are as follows:

Mosfellssveit	1,525l/s	at	86°C
Laugavegur	330l/s	at	127°C
Ellidaár	210l/s	at	93°C

Both the hot and cold water supplies in the Reykjavík area are relatively pure. Substances in solution in the hot water vary slightly from one borehole to another, ranging between 200 and 300 milligrammes per litre, and about half of this quantity is silica. The cold water contains under 70 mg/l. Only negligible numbers of bacteria have been found, so Reykjavík's water is safe for drinking without chlorination, and as it is extremely soft it is excellent for washing.

The only treatment of the hot water that is called for is degassing, because it contains dissolved gases, chiefly nitrogen which would be released and accumulate in the highest parts of the heating system (due to the decrease in presssure) and form locks in radiators. Superheated water is degassed by "flashing," lowering the pressure slightly so that the gas is released in the resulting partial boiling. In the case of water at less than 100°C degassing takes place in open cisterns. The hot borehole water is oxygen-free, meaning that it can be distributed by ordinary steel pipes without the danger of corrosion.

The city's first distribution systems were of the single-pipe type, in which the water, which was sent out at about 80°C, was discarded after passing through the consumers' radiators. Later, when the deeper boreholes were sunk in Reykjavík and water was obtained at over 100°C, two-pipe and mixed systems were introduced so that the water could be mixed with return water from the system and a resulting temperature of 80°C could be maintained.

In 1961 more than half of Reykjavík's inhabitants enjoyed geothermal space heating; by 1970 the figure had reached 94% and it has since been brought up to over 99%. As mentioned above, the Reykjavík District Heating System also extends to serve three nearby municipalities and sells water to a number of other local systems, which means that altogether the system provides about 127,000 people, or 50% of the nation, with hot water.

Multiple Benefits

In 1985, the heat supplied in the form of hot water by the Reykjavík District Heating Service, 2,200 GWh, was equivalent to that contained in 350,000 tons of oil. If the consumers had used oil instead of hot water, it would have resulted in the emission of about 3,800 tons of sulphur dioxide, 1,600 tons of nitrogen compounds and 410 tons of ash and soot. No pollution results from the use of natural hot water. In addition, geothermal water in Reykjavík currently costs only about 75% of the cheapest electricity rates.

Already the capacity of the existing supply fields for the Reykjavík system is becoming stretched: increased pumping causes a drop in water levels which in turn sends up the pumping cost. A new supply field at Nesjavellir, 26 km to the east of the city, has been acquired and experimental drillings have revealed sources of water at well over 300°C. Sixteen boreholes have been sunk at Nesjavellir, and the first stage of the development, yielding 100 MWT by heat exchange, is to be completed in 1988. Further development of the site is expected to yield up to 400 MWT, which should cover the capital area's heating requirements for many years to come. Some electrical generation is also envisaged there.

There are now 29 district heating systems in Iceland using geothermal energy, supplying about 84% of the energy used in space heating in Iceland, and also water for the country's many swimming pools. Four of these systems use high-temperature sources, the two most unusual being in the Westman Islands and on the Reykjanes peninsula, southwest of Reykjavík.

In the Westman Islands, a district heating system was established harnessing the energy in the lava which flowed in the spectacular eruption of 1973. This heat source has since seen to the heat needs of the community of 5,000, though it is expected to be exhausted in a few years' time. The Reykjanes peninsula experience is described later.

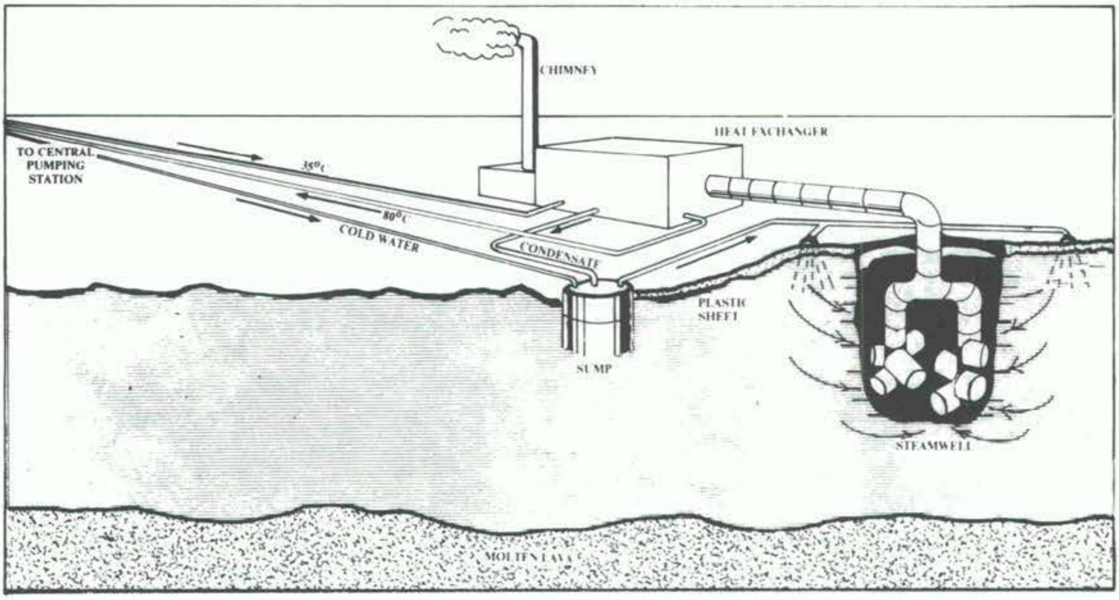

FIGURE 2

The Westmann Islands heat exchanger system draws its heat from an eruption which took place in 1973. Steam is drawn up by natural draught through the chimney. The condensate, supplemented by fresh water, is returned to the ground where it, in turn, stimulates the production of steam. Four such units, each producing about 20 MW_T , supply the town with almost all of its hot water needs.

Generation, industry, cultivation and leisure -A Review of the "Minor" Applications

Though overshadowed by the importance and scale of district heating, a number of other applications of geothermal energy have arisen in Iceland, some of them unique, and future developments may even see the balance altered significantly. Established uses include electrical generation, heat-exchange energy extraction for drying processes and greenhouse cultivation, and the newer fields include chemical production, health spas and fish farming.

Seven local municipalities in the Sudurnes area (the Reykjanes peninsula) own the majority share in the Sudurnes Regional Heating power utility at Svartsengi, the remainder being owned by the state. It was set up in 1975 to exploit geothermal resources on the peninsula and provide a heating service for neighbouring communities, and its functions were extended by acts of parliament in 1984 and 1985, by which it was permitted to generate and sell electricity and reducing the state's share to 20%.

The Reykjanes peninsula consists of highly porous lava, which is easily penetrated by both rainwater and the surrounding ocean. There is practically no surface runoff, fresh precipitation water seeping straight into the lave where it floats on the saline layer below. Shallow drillings on Reykjanes therefore recover fresh cold water, while deeper boreholes reach the heated brine at lower levels.

The geothermal fluid at Svartsengi has two-thirds the salinity of sea-water, which makes it impossible to use directly in a heating system, since the chemical content would cause corrosion, apart from the fact that it would be unsuitable for domestic use. An ingenious system of separators and heat-exchangers circumvents these problems, using the energy content of the 240°C brine to heat fresh water for the distribution system, and allowing part of the high-pressure steam to be used for electrical generation (8 MW). Another important part of the process is the degassing of the fresh water before it enters the supply.

Water from Svartsengi is pumped through over-ground pipes south to the nearby village of Grindavík at 83°C, reaching the consumer at 80°C, and north to a pumping and distribution station at Fitjar at 120°C, where it is mixed with return water from Keflavík airport and pumped to the other communities represented in Sudurnes Regional Heating. About 20,000 people are now served with hot water from the system, and since 1984 the power company has supplied electricity to the Sudurnes region, meeting about a quarter of its requirements.

Measurements at Svartsengi show that there is a rapid draw-down rate, and experiements are being carried out to see if re-injection of the discarded water is feasible. Up to now, it has been allowed to accumulate naturally in a pond beside the plant, and the precipitation of a thick layer of white silica has turned it into a "Blue Lagoon," coloured by natural reflection and refraction.

Medicinal properties have been claimed for the waters of the "Blue Lagoon." A few years ago it was discovered that some psoriasis and eczema sufferers experienced relief of their disorders after swimming in the water, and since then, facilities have been installed to enable people to use the lagoon as a health aid. Plans have recently been announced to expand and improve these facilities.

Retreat Before the Earth's Grumbles

Development of the Krafla geothermal field began in 1974, the intention being to build a 60 MW electricity generating station and reduce the dependence of the north of the country on transmission lines from the south. Early drillings uncovered very productive energy sources, one borehole alone yielding about 20 MW.

Geological studies of the Krafla area had revealed evidence of previous magmatic activity in the past, so that development there was a calculated risk from the beginning. The geological record indicated that over the past 30,000 years the average length of quiescence between spells of volcanic activity had been about 600 years. As the last recorded activity was in the 1720's, only 250 years before, it seemed safe enough to go ahead with a power station at the site.

A year after drillings began, near the end of 1975, the project was upset by magmatic action centred only two kilometres away from the site. The main problem was the release of magmatic gases, which turned the geothermal fluid acid, resulting in corrosion, and there were cases of production wells sealing up in a month because of deposits.

Drillings were duly moved away from the position of the underlying magma chamber, but while new boreholes tapped an unpolluted reservoir, problems were encountered because the ratio of steam to water was too high so that the supply did not suit the design of the turbines.

Further studies and evaluation of the experience gained at Krafla have shown that the structure of the Krafla field is far more complicated than had earlier been thought. It is a dynamic system which has not yet settled into a fixed structural pattern.

Eventually, in 1982-83, a small reservoir lying about two kilometres from the first drilling areas was developed, giving a supply sufficient for the generation of about 30 MW of electricity. One generator is in operation, producing 26 MW, but as at present there is no need for more power, a second 30 MW generator remains uncommissioned.

Industrial uses: Heat for Drying...

The Icelandic Diatomite Company *(Kisilidjan)* is the largest industrial consumer of geothermal energy in the country, and was also the first. Formed in 1966, the company is majority-owned by the state, with an American corporation and local authorities as partners. Production started in May 1968.

Diatomite is used for filtration in the food industry and as a filling material in toothpaste, paints and other products. A natural deposit of diatomaceous earth lies on the bottom of Lake Myvatn, one of the most beautiful natural attractions in Iceland. This is pumped up during the summer months, and the substance is concentrated and stored in a holding pond near the factory. Geothermal energy is used to dry the product in rotary kilns, where the proportion of solid matter is raised from 45% to 99%, and also for keeping the holding pond ice-free over the winter.

The diatomite factory is the only one in the world where geothermal heat is used for drying. Between 260,000 and 300,000 tons of steam are used each year, derived from two boreholes at temperatures of 180-200°C, and production in a typical year is of the order of 26,000 tons of dry diatomaceous earth.

For more than a decade, geothermal energy has been used for drying seaweed at Reykhólar, on the northeastern shore of Breidafjördur in the west of the country. Steam from two boreholes at 110°C is used in heat-exchangers to heat air which is then blown onto the seaweed. Two species, *Ascophyllum nodosum* and *Laminaria digitata*, are harvested in Breidafjördur and exported to a wide range of countries for human consumption, for use as fodder additives and for processing in chemical and cosmetics industries. Annual production is about 4,500 tons, and the Icelandic product can command good prices on world markets largely because of the pollution-free drying process and the resultant high quality.

...and Concentrating Chemicals

A few kilometres southwest of Svartsengi, the chemical properties of geothermal brine are being treated as an industrial resource by Reykjanes Geo-Chemicals, a production company owned by the state, local communities and individuals. On the company's land is one of the most powerful boreholes in the world, the 1,445 metre-deep R9, which has an energy potential of 165 MWT, and is as yet untapped.

Since its foundation in 1981, the company has operated mainly on an experimental basis, using geothermal energy and brine from one of the test boreholes in the area, drilled 13 years ago. The borehole yields a mixture of brine and steam in the ratio of 3:1 at a temperature of 180°C and a pressure of 10 bar. The plant uses 50 tons of steam per hour. Production to date has concentrated mainly on salt (about 2,000 tons a year), but diversification into other chemicals is now taking place, along with an expansion of salt production to 6,000 tons.

In the last few months a technique has been developed at Reykjanes Geo-Chemicals to control the precipitation of silica present in the geothermal brine. Using geothermal heat, the brine is concentrated by evaporation until the silica is at saturation point. Actual precipitation of the substance is delayed by the injection of hydrochloric acid, the resultant acidity being offset by the addition of sodium hydroxide. Fine adjustments of the concentration make it possible to determine the size of the particles in which the silica precipitates, so that instead of solidifying uncontrolled on equipment surfaces as a film, blocking pipes and heat-exchangers, it takes the form of a slurry.

Three products based on the silica slurry are in development stage: an ointment for psoriasis sufferers, one for teenage acne problems and a cosmetic mask.

Further evaporation of the water after the extraction of the silica yields salt, which is crystallised in open pans.

Reykjanes Geo-Chemicals has also started production of carbon dioxide, with 700 tons a year as an initial production rate. A large domestic market potential is envisaged for this, both in liquid form for use in greenhouse atmosphere adjustment, soft drinks and shock freezing, and as dry ice for the transportation of food, preservation of in-flight meals and for other purposes.

Future production plans at Reykjanes Geo-Chemicals include the export of a "sea concentrate" with an ion balance the same as that of the human body, for therapeutic purposes, and the extraction of a wide range of chemicals from the brine, including lithium salts, bromide salts, calcium chloride, and potassium chloride.

Hot Water for Food and Health

Greenhouse cultivation plays an important role in Iceland, since the climate places narrow limits to the range of plants that can be grown under natural conditions. Commercial greenhouses account for all the flowers sold in Iceland, and also more than 1,000 tons a year of vegetables such as tomatoes, cucumbers and peppers. The total area of commercial greenhouses is now 170,000 m^2. It is also increasingly common for people to have small private greenhouses in their gardens, using the waste water from their domestic heating systems.

An area in which Iceland has made a late but promising start is fish farming. Estimates of the potential indicate that aquaculture products could account for a quarter of the nation's exports by the end of the century. The role of geothermal enrgy *per se* is small, though important, since a cheap supply of warm water for use in accelerating the growth rates of the fish is a great economic advantage. The industry's greatest strength lies in the fact that there are plentiful supplies of borehole water, both warm and cold, which is bacteria-free, circumventing the need to resort to chemical treatment or the use of antibiotics to prevent disease. Consequently the fish are of higher quality and have greater appeal as a truly natural product.

Finally, the oldest application of geothermal water, for swimming and bathing, is still very much in existence today. There are 111 public swimming pools in Iceland (one pool for every 2,200 people), with a combined volume of 30,000 m^3, and swimming is an important part of the national way of life.

While passive geothermal energy use has existed for centuries, for laundering and bathing, a more active approach was not found until the nineteen-twenties. Since then, in Iceland as elsewhere, natural hot water and steam have been harnessed for wider benefits. The application of new technologies, as well as wide-ranging research facilities, have been well developed in this small Atlantic nation which borders on the Arctic. That experience is now being shared through the United Nations Development Programme and the United Nations University--the latter body having its geothermal studies department located in Reykjavík.

Suggested Additional Reading

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SPRING CAPPING

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INTRODUCTION

Springs are points where water from an underground source is able to seep to the surface. Spring water comes to the surface because a layer of material such as clay or rock prevents it from flowing downwards. The best places to look for springs are the slopes of hillsides and river valleys. Green vegetation at a certain point in a dry area may also indicate a spring. The flow of a spring is governed by several factors: watershed collection area, percolation rate of water through the ground, thickness of ground above the aquifer, and the storage capacity of the soil.

Springs are seasonally variable, tending to lag behind the seasonal rainfall patterns (springs can give normal flows well into the dry season before tapering off, and may not resume full flow until after the rainy season is well underway).

Due to ground percolation and filtration, most springs are free of pathogenic organisms that may casue health problems. Some springs, however, flow through limestone, or geologic cracks and fissures in the rocks. In such cases, filtration effects are minimal and the flow may be contaminated.

SELECTING THE SPRING

Four criteria must be considered when selecting a spring as a potential water source. It must:

1. have an adequate and reliable spring flow;
2. be safe to drink;
3. be convenient and accessible to the users; and
4. be possible to cap the spring.

For the first criterion, determining the adequacy of spring flow can be done by a very simple method. It is necessary to have a bucket or container of a known volume plus a stopwatch or a wristwatch with a sweep-second-hand. With a watch, measure the amount of time that it takes for the bucket to fill with water. Divide the volume of water by the amount of time to find the rate of flow in liters per minute.

For example, if a 10-liter bucket fills in 45 seconds, the rate of flow is:

$$\frac{10 \text{ liters}}{45 \text{ seconds}} = 0.22 \text{ liters/second}$$

0.22 liters/second x 60 seconds (minute) = 13.2 liters/minute

It is then easy to determine the volume of water available during a 24-hour period. Multiply the number of liters per minute by 60 minutes per hour to find liters per hour. For example:

13.2 liters/minute x 60 = 792 liters/hour

Then, take the flow in liters per hour and multiply it by 24 hours per day to find the daily flow. For example:

792 liters/hour x 24 hours/day = 19,008 liters per day

This amount can then be compared to the daily needs of the community. The daily need is computed by multiplying the number of users by the number of liters each person will use in one day. For example, if there are 300 people using 40 liters per day, the daily water usage is 12,000 liters. Animals may be watered from the spring also. The following are approximate daily minimum water needs per animal: cows 10 - 15 liters; buffalo 15 - 20 liters; goats 5 - 10 liters; chickens 5 liters per dozen.

To be reliable, the spring flow must be constant and adequate through both wet and dry seasons.

For the second criterion, a sanitary survey will help determine whether or not the spring water is safe to drink.

The first step in a sanitary survey of a spring site is to determine the physical conditions above the point where the water flows from the ground. If there are large openings or fissures in the bedrock above the spring, contamination of the spring from surface runoff may occur. Surface runoff enters the ground through the fissures and contaminates the spring water underground.

Find the true source of the spring. Many times, a small stream disappears into the ground through a fissure and emerges again at a lower elevation. What appears to be a spring actually may be surface water that has flowed underground for a short distance. The water is generally contaminated and may flow only during the wet season.

Determine if there are sources of potential fecal contamination. Livestock areas, septic tanks and other sewage disposal sites are sources of contamination. If they are located above the source or closer than 100 m to it, contamination may occur and disease-causing bacteria can enter the water.

The second step in a sanitary survey is to study the area at the spring site. the type of soil may indicate that contamination is likely. Filtration may be poor if permeable soil deeper than 3 m is within 15 m of the spring. Water passes quickly through coarse soils and impurities are not filtered out. If this condition exists, or if there is any suspicion of contamination, a water analysis must be done.

A spring flowing from limestone or highly fractured rock may be subject to contamination. Earth movements create fissures and cracks in limestone allowing surface runoff to enter the ground rapidly with little or no filtration of impurities. If a spring flows from a limestone bed, check the water after a heavy rain. If it appears turbid, suspect surface contamination and either analyze the water or choose a better site. A sample sanitary survey form for evaluating a spring can be found on page 80.

To meet the third criterion, a spring should be as close to the users as possible to minimize the daily work required by women and children to collect and carry water. Difficult and hazardous crossings such as roads, log bridges or infested waters would be avoided.

Several factors must be considered in determining if it is technically possible to cap the spring, the fourth criterion.

- A spring should have an adequate slope for proper drainage.
- It should have protection from flooding and diversion of watershed runoff.
- The slope should be steep enough so that a collection vessel can be placed underneath the discharge pipe.
- Labor and materials such as gravel, rock, sand and clay should be locally available.
- There should be a solid footing on well-drained ground for the structure.

DESIGN OF SPRING STRUCTURES

The choice of the structure for spring protection depends on the geologic conditions of the area, the type of spring, the materials available and the skill level of available labor. The design process should result in the following three items which should be given to the construction supervisor:

1. A map of the area. Include the location of the spring, the locations of users' houses distances from the spring to the users, elevation and important landmarks. Figure l is an example of such a map.

2. A list of all labor, materials and tools that are needed. This will help make sure that adequate quantities of materials are available so construction delays can be prevented.

3. A plan of the spring box with all dimensions as shown in Figure 2. This plan shows a top, side and front view, and the dimensions of a cover for a spring box lm x lm x lm.

There are several possible designs for spring boxes, but generally their basic features are similar. Spring boxes serve as collectors for spring water. They are sometimes used as storage tanks when a small number of people are being served and the source is located near the users. When larger numbers of people are served, the water collected in the spring box flows to larger storage tanks. The two basic types of spring boxes discussed in this paper are a box with one pervious side for collection of water from a hillside, and a box with a pervious bottom for

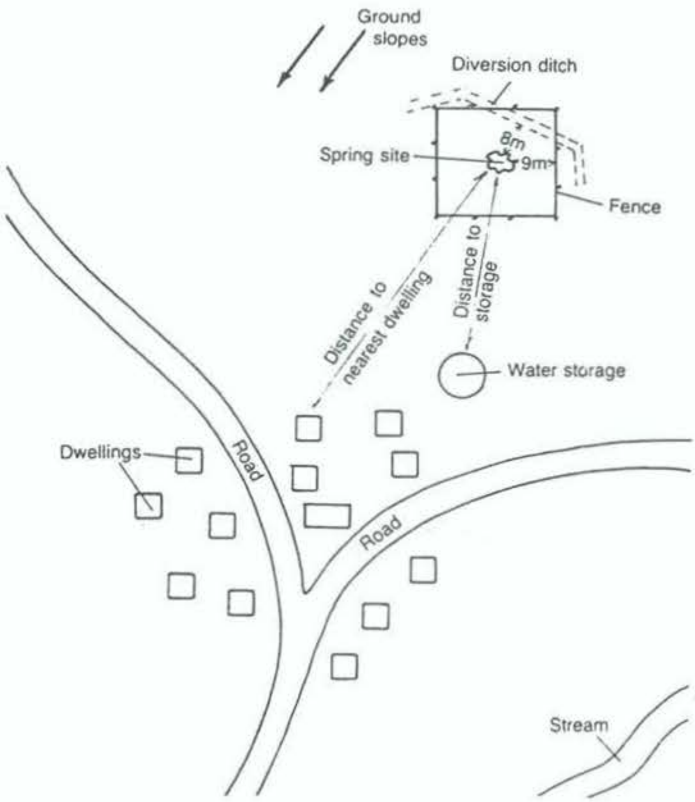


Figure 1

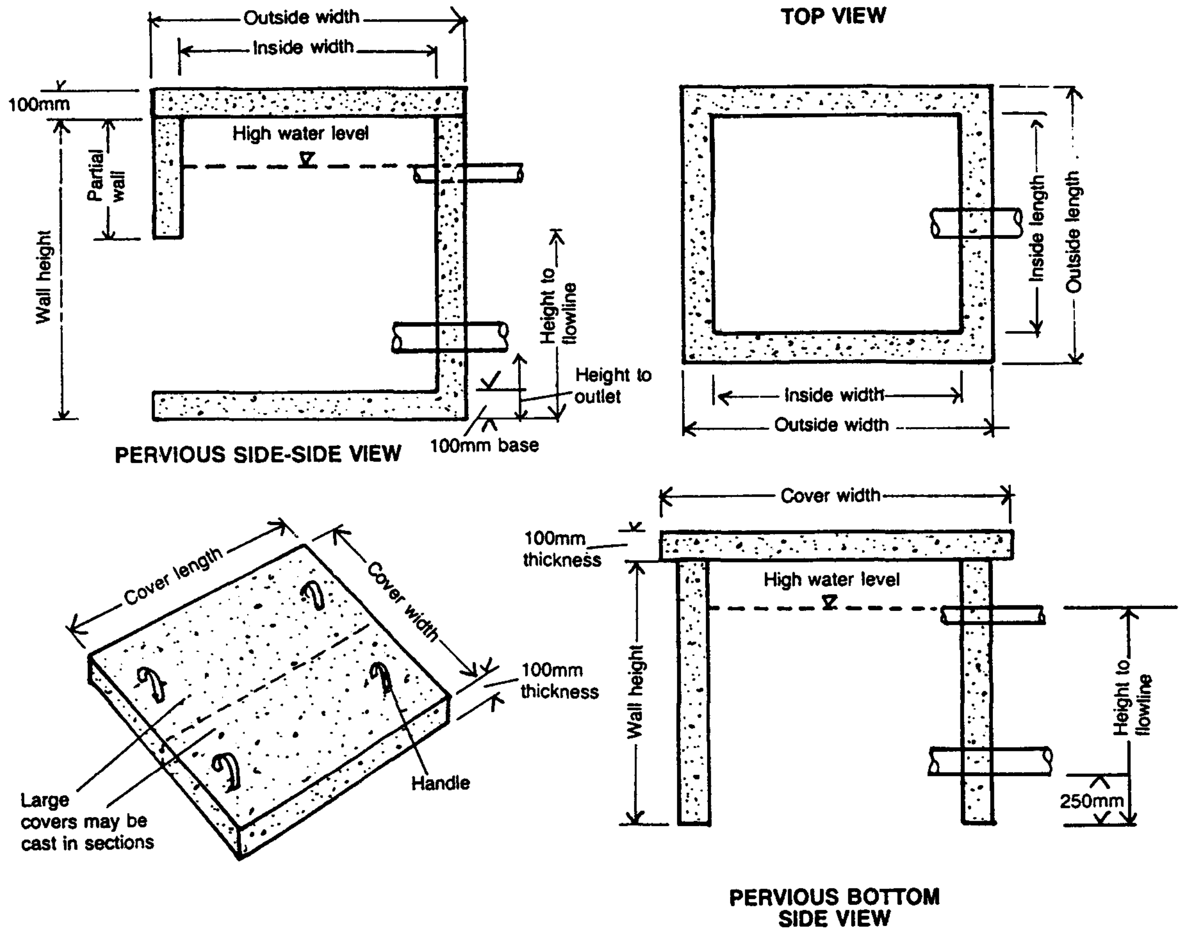
collection of spring water flowing from a single opening on level ground. To determine which design to use dig out around the area until an impervious layer is reached, locate the source of the spring flow and design to fit the situation.

Spring Box with Open Side. A spring box with a pervious side is needed to protect springs flowing from hillsides. The area around the spring must be dug out so that all available flow is captured and channelled into the spring box.

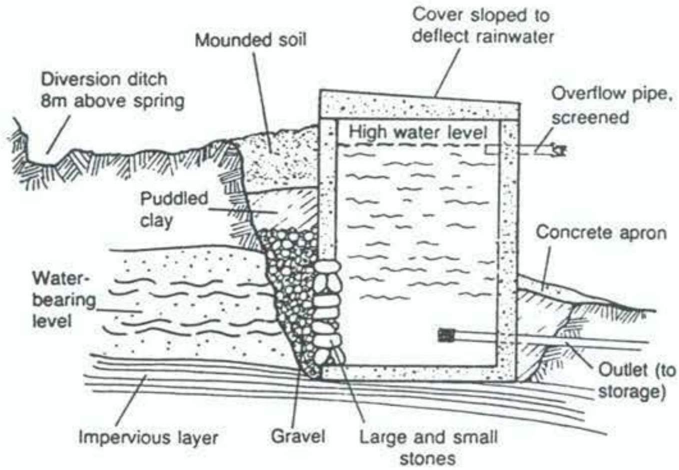
After this has been done, a collection box can be built around the spring outlet as shown in Figure 3. The dug-out area should be lined with gravel. The gravel placed against the spring opening serves as a foundation for the box and prevents the spring water from washing soil away from the area. The gravel pack also filters suspended solids. The gravel-filled area should be between 0.5-lm wide depending on the size of the spring collection area. To ensure that no contamination reaches the water, the gravel pack should be at least lm below the ground surface. This is done either by locating the spring catchment in the hillside or by raising the ground level with backfill.

Caution must be taken not to disturb ground formations when digging out around the spring. Without care, the flow of the spring may be deflected in another direction or into another

Figure 2



Spring Box Design



Spring Box with Open Side

Figure 3

fissure. The area must, however, be dug out enough so that the spring box fits into impermeable material. In cases where the box does not reach impermeable material, puddled clay should be used to seal the area around the sides of the spring box.

Spring Box with Open Bottom. If a spring flows through a fissure and emerges at one point on level ground, a spring box with an open bottom can be developed as shown in Figure 4. The area around the spring is dug out until an impermeable layer is reached. The area around the spring is then leveled and lined with gravel. The spring box is placed over the spring and gravel to collect the flow, and clay or concrete is packed around the box to prevent seepage between the ground and the box. Sometimes a small sump can be built at the bottom so that sediment settles in one place.

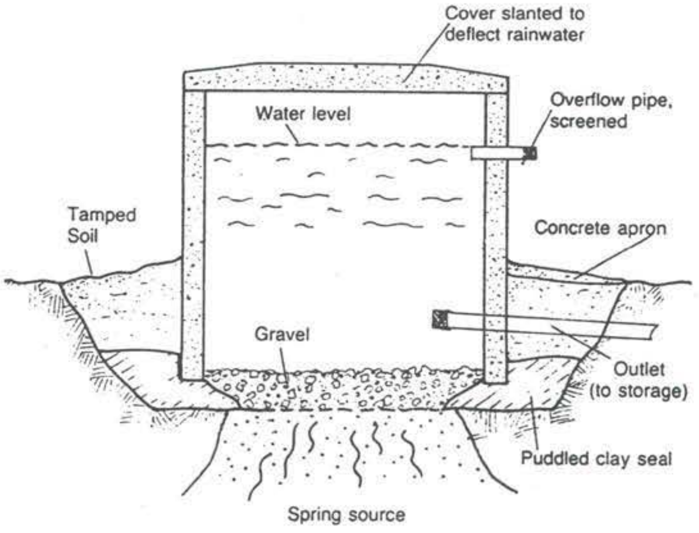
The design of both types of spring boxes is basically the same and includes the following features:

a. a water-tight collection box constructed of concrete , brick, clay pipe or other materials,

b. a heavy removable cover that prevents contamination and provides access for cleaning,

c. an overflow pipe, and

d. a connection to a storage tank or directly to a distribution system. The spring box with an open bottom is simpler and cheaper to construct. Generally, on level ground the flow from only one source must be captured and collection of all available flow is much easier. Costs are lower because less digging and fewer materials are required.



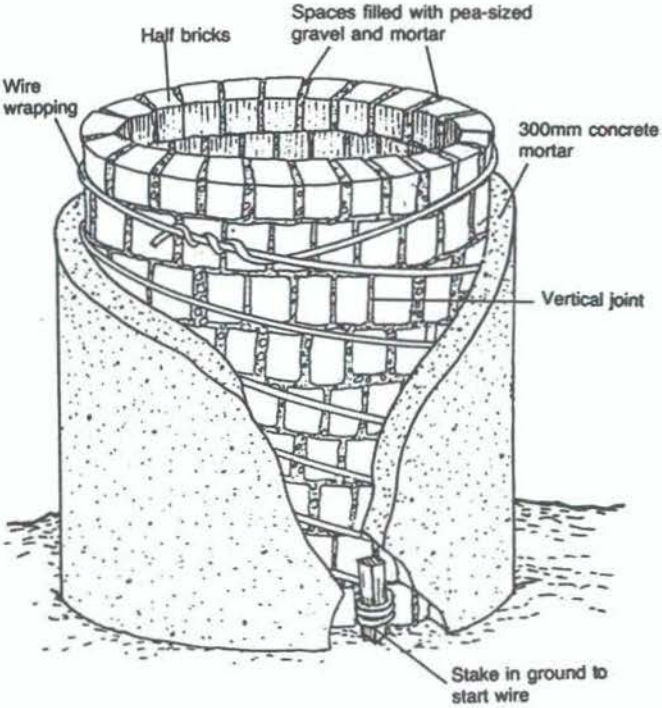
Spring Box with Open Bottom

Figure 4

The spring box should be constructed at the spring site for easy installation. If the appropriate materials are available, the spring box should be made of concrete. Information on the use of concrete is included in Worksheet A. Three sides of the spring box must be impervious and depending on the type of spring selected for development, either the bottom or the upslope side must be pervious or open. The upslope side of an open-sided spring box can be constructed partially with concrete and partially with large rocks and gravel as shown in Figure 3. Large rocks support the spring box and allow water to enter. Smaller stones should be used between the large rocks to close large openings so that sediment is filtered from the water.

If materials for building a concrete box are not available, or are expensive, there are alternatives that are particularly useful in developing a single source spring. Large prefabricated clay or concrete tubes, like regular spring boxes, can be placed around the spring. Water rises in the tube and flows out the outflow pipe. Rings for collecting spring water can even be constructed using bricks and mortar. Half or broken bricks can be used to build a ring as shown in Figure 5. The bricks are laid in a circular pattern, so that vertical joints do not line up. Spaces between the bricks are filled with gravel and mortar. Bricks are laid until a height of between 0.9-1.2m is reached. The diameter may vary but should be around 0.7-1.0m. An outlet and overflow pipe should be placed in the structure before installation and with reinforcement added. This type of structure is very practical and inexpensive to construct. Little cement is needed and locally available materials can be used.

The capacity of the spring box depends on whether it is being used for storage or pre-storage. If the spring box is used for storage, it should be large enough to hold a volume of water equal to the needs of the users over a 12-hour period. For example: if 100 people each use 25 liters of water per day, the amount of water consumed in 12 hours is 1,250 liters. There are 1,000 liters per m^3. Therefore, the volume of the spring box should be $1.25m^3$. (Volume = length x width x height). If the collection box is used only for pre-storage and water flows on to another storage tank, the collection box can be smaller.



Brick Spring Box

Figure 5

A reinforced concrete cover must be constructed to protect the tank from outside contamination. The cover should be cast in place to ensure proper fit. It should extend over the spring box about 0.1m on each side so rain does not fall at the base of the spring box. The cover should be heavy enough so children cannot lift it off.

The spring box should have an overflow pipe. The pipe is placed a little below the maximum water level and at least 0.15m above the floor of the tank. If the pipe is above the maximum water level, water will not flow out and pressure is created in the tank. The pressure could cause a back-up and diversion of the spring. The overflow pipe should be covered with a screen fine enough to keep out mosquitoes and strong enough to keep out small animals. The size of the pipe depends on the flow of the spring. A rock drain or concrete slab should be placed outside the tank below the overflow pipe to prevent erosion near the base and to carry the water away from the spring. A pipe which extends 3-5m from the tank is desirable in order to keep the site free from still water.

An outlet pipe for connection to a distribution system should be located at least 0.1m above the bottom of the spring box to prevent a blockage due to sediment build up. The pipe size depends on the gradient to the storage tank and the spring flow. A general rule to follow is that with a one percent gradient, a 30mm pipe should be used. A gradient of between 0.5 and one percent requires a 40mm pipe, while a 50mm pipe should be used for gradients of less than 0.5 percent. In some cases, the same pipe will be both outlet and overflow. The outlet pipe should slope downward for best flow.

After the spring box is installed, the space behind it must be filled with soil and gravel. The gravel is the bottom layer. On top of it, a water-tight layer should be formed to prevent the entrance of surface water. This can be done with concrete or puddled clay. Puddled clay is a mixture of clay and water formed into a layer 150mm thick. The layer is placed on the ground and worked in by trampling on it. Several layers of puddled clay should be placed behind the box.

After sealing the area, the box can either be completely covered with soil or stand above the ground surface. The box should be at least 0.3m above ground level so that runoff does not enter it. For further sanitary protection, a ditch should be dug at least 8m above the spring box to take surface water away from the area. The soil from the ditch should be piled on the downhill side to make a ridge and keep surface water away. A fence around the area will keep animals from getting near the spring box and help prevent contamination and destruction of the area. The fence should have a radius of between 7-8m.

In addition to a location map and design drawings, give the person in charge of construction a materials list similar to Table 1 showing the number of labourers and types and quantities of materials needed to construct the spring protection. Some quantities will have be determined in the field by the person in charge of construction.

Table 1: Sample Materials List

Item	Description	Quantity	Estimated Cost
Labour	Foreman	______	______
	Laborers	______	______
Supplies	Portland cement	______	______
	Clean sand and gravel, if available, or locally available sand and gravel	______	______
	Water (enough to make a stiff mixture)	______	______
	Wire mesh or reinforcing rods	______	______
	Galvanized steel or plastic pipe (for outlets, overflow, and collectors	______	______
	Screening (for pipes)	______	______
	Boards and plywood (for building forms)	______	______
	Old motor oil or other lubricant (for oiling forms)	______	______
	Baling wire	______	______
	Nails	______	______
Tools	Shovels and picks (or other digging tools)	______	______
	Measuring tape or rods	______	______
	Hammer	______	______
	Saw	______	______
	Buckets	______	______
	Carpenter's square or equivalent (to make square edge)	______	______
	Mixing bin (for mixing concrete)	______	______
	Crowbar	______	______
	Pliers	______	______
	Pipe wrench	______	______
	Wheelbarrow	______	______
	Adjustable wrench	______	______
	Screwdriver	______	______
	Trowel	______	______

Total Estimated Cost ______

Concrete. Concrete is the major material used in the construction of spring boxes and cutoff walls. Concrete is a mixture of Portland cement, clean sand and gravel in a fixed proportion. The proportion generally used is one part cement, two parts sand and three parts gravel (l:2:3). Water is used to mix the concrete. Twenty-eight liters of water should be used for each bag of cement. Worksheet A will help determine the amount of materials needed. Use the worksheet in making the following calculations.

Worksheet A: Calculating Quantities Needed for Concrete
(Calculations for a box 1m x 1m x 1.0m with open bottom)

Total volume of box = length (l) x width (w) x height (h)

Thickness of walls = 0.10m

1. Volume of top = l 1.2 m x w 1.2 m x t 0.10 m = 0.144 m^3
2. Volume of bottom = l 0 m x w 0 m x t 0 m = 0 m^3
3. Volume ot two sides = l 1 m x w 1 m x t 0.10 m x 2 = 0.20 m^3
4. Volume of two ends = l 1 m x w 1 m x t 0.10 m x 2 = 0.20 m^3
5. Total volume = sum of steps 1, 2, 3, 4, 5 = 0.54 m^3
6. Unmixed volume of materials = total volume x 1.5: 0.54 m^3 x 1.5 = 0.81 m^3
7. Volume of each material (cement, sand, gravel, 1:2:3):
   cement: 0.167 x volume from Line 6 0.81 = 0.13 m^3 cement.
   sand: 0.33 x volume from Line 6 0.81 = 0.26 m^3 sand.
   gravel: 0.50 x volume from Line 6 0.81 = 0.4 m^3 gravel.
8. Number of 50kg bags of cement = $\frac{\text{volume of cement}}{\text{volume per bag}}$
   volume of cement 0.13m^3 - .033m3m^3/bag = 4 bags.
9. Volume of water = 28 liters x 4 bags of cement = 112 liters.

Note:
1. Do not determine volume for an open side or bottom.
2. The top slab has a o.1m overhang on each side.
3. The same calculations will be used to determine the quantity of materials for construction of a seepage wall.
4. To save cement a 1:2:4 mixture can be used.

1. Calculate the volume of mixed concrete needed (length x width x thickness; (Worksheet A, Lines l-5).

2. Multiply this number by l.5 to get the total volume of dry loose material (cement, sand and gravel) needed (Worksheet A, Line 6).

3. Add the numbers in the proportion in order to find the fraction of the total needed for each material (l:2:3 = 6, so l/6 of the mixture should be cement, 2/6 sand and 3/6 gravel. In decimals, this is 0.l67 cement, 0.33 sand and 0.50 gravel).

4. Determine the amount of each material needed by multiplying the volume of dry mix from Step 2 by the proportional amount for each material (0.167 x volume of dry mix = total amount of cement needed; Worksheet A, Line 7).

5. Divide the volume of cement needed by .033m^3 (33 liters), which is the amount of cement in a 50Kg bag, to find the number of bags of cement required. When determining the amount of cement, figure to the largest whole number (Worksheet A, Line 8).

6. An extra quantity of cement should be figured into the total for use in grouting and sealing areas around the outlet pipes.

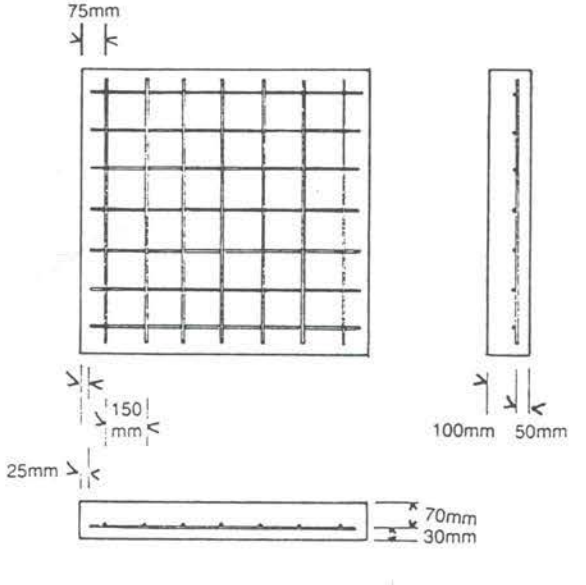
7. Calculate the amount of water needed to mix the concrete (28 liters of water per bag of cement; Worksheet A, Line 9).

8. Extra gravel will be needed for backfill of areas behind springs. Graded gravel is preferable, but local materials can be used if necessary. Calculate the volume of the area to be backfilled by taking length x width x height of area.

Reinforced Concrete. Concrete can be reinforced to give it extra strength. This is best done with wire mesh or specially made steel rods. Reinforced concrete sections must be at least 0.lcm thick. Reinforced concrete should be used for all spring box covers and for the walls of seep structures. If wire mesh is used, the quantity needed will be approximately equal to the area of the slab being constructed. If steel bars (rods) are used, they should be placed in the wooden form before the concrete is poured. Rods of l0mm diameter should be used.

The reinforcing rods should be located as follows:

- So that the rods are at least 25mm (o.25m) from the form in all places;
- So that the rebar rests in the lower part of the cover; two-thirds the distance from the top or 70mm from the top of a 100mm slab;
- So that a 150mm (0.15m) space lies between a parallel rod in a grid pattern as shown in Figure 6.



Placement of Rebar in Concrete Slab

Figure 6

Where the reinforcing rods cross, they should be tied together with wire at each point of intersection.

To determine the number of reinforcing bars, divide the total length or width of the spring box cover by 0.15m (distance between bars). For example, $\frac{1.2m}{0.15m} = 8$ bars.

To determine the length of each bar, subtract 0.05m (0.25m each side) from the total length or width of the cover. For example, 1.2m - 0.05m = 1.15m.

Pipes. Outlet pipes can be of galvanized steel or plastic, depending on what is available. Galvanized steel is preferable because of its strength. Steel pipe lasts longer and does not shatter like plastic pipe. Intake pipes should be either clay, perforated plastic, open-joint cement or, in some cases, bamboo. The choice again will depend on availability of materials and cost. The pipe should have a minimum diameter of 50mm to be sure that an adequate supply of water enters the collection system. All pipes must be laid with a uniform slope to prevent air locks in the system.

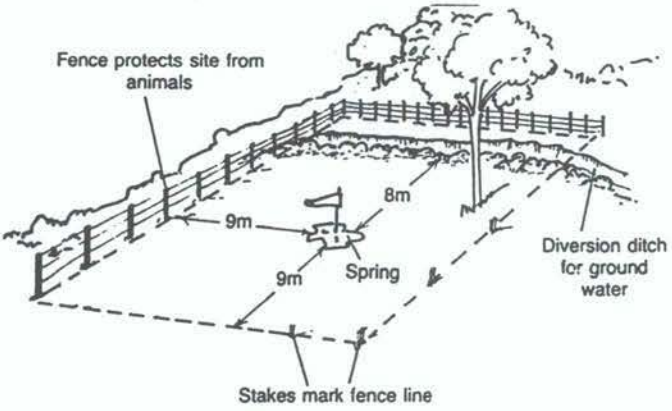
When labour requirements, materials and tools have been decided on, prepare a materials list similar to Table 1 and give it to the construction supervisor.

CONSTRUCTION STRUCTURES FOR SPRINGS

GENERAL CONSTRUCTION STEPS

Follow the construction steps below. Refer to the diagrams noted during the construction process.

1. Locate the spring site and, using measuring tape, cord and wooden stakes or pointed sticks, mark out the construction area as shown in Figure 7.



Preparation of Spring Box Site

Figure 7

2. Dig out and clean the area around the spring to ensure a good flow. If the spring flows from a hillside, dig into the hill far enough to determine the origin of the spring flow. Where water is flowing from more than one opening, dig back far enough to ensure that all the water flows into the collecting area. If the flow cannot be channeled to the collection area because openings are too separated, drains will have to be installed. Information on the installation of drains appears in the section on the development of seep collection systems.

Flow from several sources may be diverted to one opening by digging far enough back into the hill. When digging out around the spring, watch to see if flow from the major openings increases or if flow from minor seeps stops. These signs indicate that the spring flow is becoming centralized and that most of the water can be collected from one point. The goal is to collect all available water from the spring. It is generally easier to collect water from one opening than from several.

Dig down deep enough to reach an impervious layer. An impervious layer makes a good foundation for the spring box and provides a better surface for a seal against underflow. If an impervious layer cannot be reached, attempt to construct the box in the most impermeable soil you can find.

3. Pile loose stones and gravel against the spring before putting in the spring box. The stones serve as a foundation for the spring box and help support the ground near the spring opening to prevent dirt from washing away. They also provide some sedimentation. For fast flowing springs, large stones with gravel between them should be placed around the spring to prepare a good solid base. Figure 3 shows an example of gravel and stone placed between the spring box and the spring.

If a spring flows from a single opening on level ground, dig out around the opening to form a basin. Be sure to dig down to impervious material to form the base. Line the basin with gravel so that the water flows through it before it enters the spring box. This is shown in Figure 4.

4. Approximately 8m above the spring site, dig a trench for diverting surface runoff. The trench must be large enough to catch surface flows from heavy rains. If large stones are available in the construction area, use them to line the diversion trench to increase the rate of runoff and prevent erosion.

5. Mark off an area about 9m by 9m for a fence. Place the fence posts 1 m apart and string the fence. A fence is useful to prevent animals from frequenting the spring site.

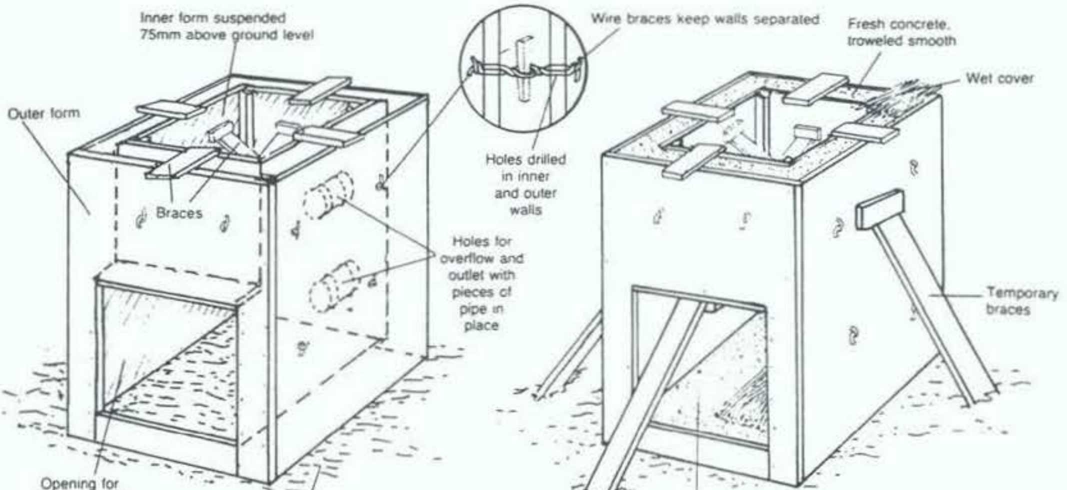
CONCRETE CONSTRUCTION STEPS

In order to have a strong structure, concrete must cure at least seven days. Strength increases with curing time. Therefore, construction of the spring box should begin at the site during the first day of work. If the concrete is poured on the first day, seven days will be available for site preparation before the spring box is put in place. Be sure that all tools and materials needed to build the forms and mix the concrete are at the construction site.

1. Build wooden forms. Cut wood to the appropriate sizes and set up the forms on a level surface. The outside dimensions of the forms should be 0.1m larger than the inside dimensions. A form with an open bottom should be built for a spring flowing from one spot on level ground. For springs from hillsides, a spring box form with a partially open back must be constructed as

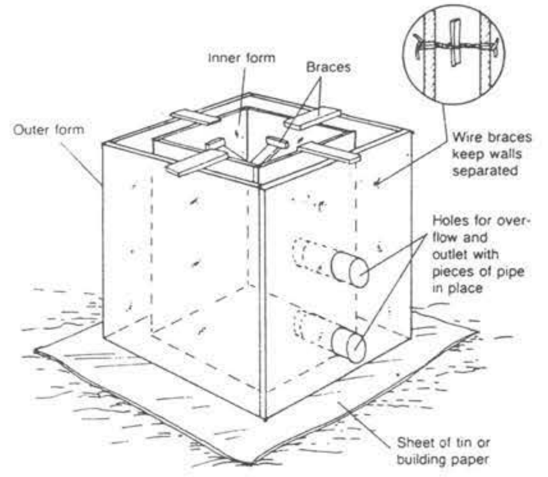
shown in Figures 8 and 9. The size of the opening depends on the area which must be covered to collect the water. When building forms for a box with a bottom, be sure to set the inside forms 0.1m above the bottom for the floor. This is done by nailing the inside form to the outside form so that it hangs 0.1m above the floor. Make holes in the forms for the outflow and overflow pipes. Place small pieces of pipe in them so that correctly sized holes are left in the spring box as the concrete sets. A form for the spring box cover must also be built. Build all forms at the site.

Forms must be well secured and braced before pouring the concrete. Cement is heavy and the forms will separate if the bracing is not strong enough. One useful method is to tie the braces together with wire as shown in Figures 8 and 9. Drill holes in the forms and place wire through them. Using a stick, as shown, twist the wire to tighten it and force the forms together.



Forms for Spring Box with Open Side

Figure 8



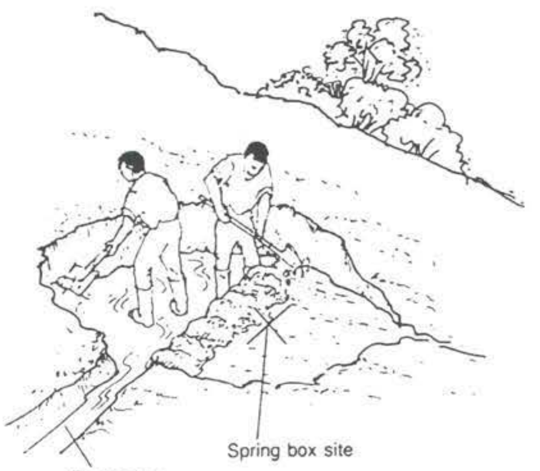
Forms for Spring Box with Open Bottom

Figure 9

2. Set the forms in place. They should be either at the permanent site of the spring box or nearby so it will not be difficult to move the completed structure. If the forms are set and concrete is poured at the permanent site, water must be diverted from the area. This usually can be done easily by digging a small diversion ditch as shown in Figure 10. Make sure that no water reaches the forms so that the concrete can cure.

If water diversion is difficult, build the forms and pour concrete on a level spot very near the spring. Once the concrete dries, remove the forms and set the completed structure in place. This will require six to eight people.

3. Oil the forms. Put old motor oil on the wooden forms so the concrete will not stick to them.



Excavating Spring Site

Figure 10

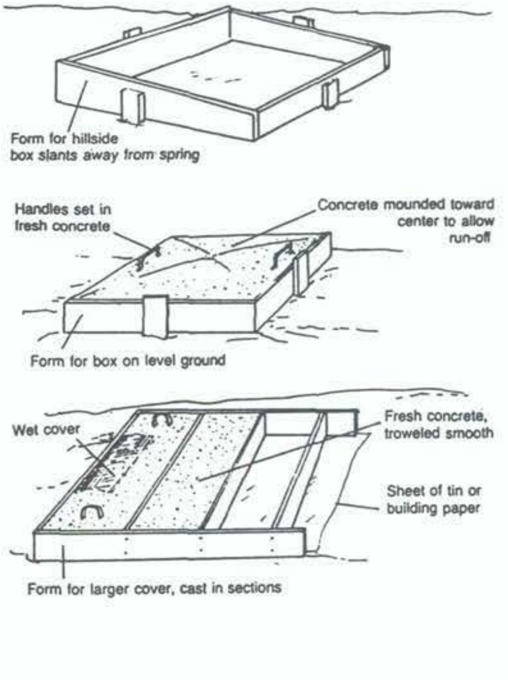
4. Prepare the reinforcement rods in a grid pattern for placement in the forms for the spring box cover. Make sure there is 0.15m between the parallel bars and that the rods are securely tied together with wire. Then position the reinforcing rods in the form. See **Figure 6** for an example of reinforcing rod placement in the spring box cover. Major reinforcing is not needed for the spring box walls but some minor reinforcing around the perimeter of the walls is good to prevent small cracks in the cement. Four bars tied together to form a square should be placed in the forms.

5. Mix the concrete in a proportion of one part cement, two parts sand and three parts gravel (1:2:3) Add just enough water to form a thick paste. Too much water produces weak concrete. In order to save cement, a mixture of 1:2:4 can be used. This mixture is effective with high-quality gravel.

6. Pour the concrete into the form. Tamp the concrete to be sure that the forms are filled completley and that there are no voids or air pockets that can weaken it. Smooth all surfaces. Smooth the concrete for the spring box cover so the middle is a little higher than the sides (convex shape), as shown in Figure 11. This will allow water to run off the cover away from the spring box.

7. Cover the concrete with canvas, burlap, empty cement bags, plastic, straw or some other protective material to prevent it from losing moisture. The covering should be kept wet so water from the concrete is not absorbed. If concrete becomes dry, it no longer hardens, its strength is lost, and it begins to crack. Keep the cover on for seven days or as long as the concrete is curing.

8. Let the concrete structures set for seven days, wetting the concrete at least daily. After seven days, the forms can be removed and the box can be installed.



Forms for Spring Box Cover

Figure 11

When constructing a masonry ring to protect a spring, follow the construction steps listed below:

1. Mark out a circle on the ground with the diameter of the proposed masonry ring.

2. Using half bricks, place a circle of brick around the outside of the ring.

3. Fill the spaces between the bricks with pea gravel and mortar mixed in a proportion of one part cement to three parts sand. As mortar is applied, add the next line of bricks. Be sure the vertical joints do not line up.

4. When reaching the desired height, strengthen the structure using baling, barbed or any available wire. Put a stake in the ground next to the ring and attach the wire to it. Wrap the wire around the ring several times as shown in Figure 5. Once the wire is wrapped around, secure and cut it.

5. Mix mortar in the proportion of one part cement to three parts sand. Cover the outside of the ring with a layer of mortar. The layer should be thick enough to cover the wire completely.

6. A circular cover should be built. Follow the same techniques as for the construction of concrete spring box covers.

INSTALLING A SPRING BOX

The spring box must be installed correctly to ensure that it fits on a solid, impervious base and that a seal with the ground is created to prevent water seeping under the structure.

1. Place the spring box in position to collect the flow from the spring. If the flow comes from a hillside, the back of the spring box will be open. Stones should be placed at the back of the box to provide support for the structure and to allow water to enter the spring box. Figure 4 shows the placement of open-jointed rock in a completely installed spring box in a hillside. On level ground, be sure that the spring box has a solid foundation of impervious material. Place gravel around the box or in the basin so that water flows through it before entering the box.

2. Seal the area where the spring box makes contact with the ground. Use concrete or puddled clay to form a seal that prevents water from seeping under the box.

3. Be sure that the area where the spring flows from the ground is well lined with gravel, then backfill the dug-out area with gravel. The gravel fill should reach as high as the inlet opening in the spring box so that the water flowing into the structure passes through gravel. In Figure 4, the gravel layer reaches the same level as the open stone wall. For spring boxes on level ground, gravel backfill is unnecessary.

4. Place the pipes in the spring box. Remove the pipe pieces used to form the holes and put in the pipe needed for outflow and overflow. On both sides of the wall, use concrete to seal around the pipes so water does not leak out from around them. Place screening over the pipe openings and secure it with wire.

5. Disinfect the inside of the spring box with a chlorine solution. Before the spring box is closed, wash its walls with chlorine. Follow the directions for disinfection in "Disinfecting Wells."

6. Place the cover on the spring box.

7. Backfill around the area with puddled clay and soil. On a hillside, place layers of puddled clay over the gravel so that they slope away from the spring box. The clay layer should nearly reach the top of the spring box and should be tamped down firmly to make the ground as impervious as possible. If only soil is used for backfill, it would have to be at least 1.5-2m deep so that contaminated water could not reach the gravel layer. For springs on level ground, clay should be placed around the box. The clay foundation should slope away from the spring box so that water runs away from the spring outlet.

8. Backfill the remaining areas with soil to complete the installation.

Worksheet B. Questions to be Answered by a Sanitary Survey

		Yes	No
1.	Do potential sources of surface contamination exist		
	a) above the site or in the watershed?	___	___
	b) at the site?	___	___

If yes, determine these sources and

a) remove sources of contamination, and/or
b) protect the water supply, or
c) find a more acceptable water supply.

		Yes	No
2.	Do potential sources of fecal contamination exist		
	a) above the site or on the watershed?	___	___
	b) at the site?	___	___

If yes, determine these sources and

a) analyze the water, or
b) remove sources of contamination.

If level of coliform bacteria greater than 10 organisms per 100ml of water,

a) water must be treated, or
b) alternative source must be found.

		Yes	No
3.	Does the water source have unacceptable chemical or physical qualities such as:		
	a) colour?	___	___
	b) turbidity (1) all the time?	___	___
	(2) after a rainstorm?	___	___
	c) unpleasant odour?	___	___
	d) a lot of salt?	___	___
	e) excessive algae?	___	___
	f) excessive flourides?	___	___
	g) hardness?	___	___

If the answer is YES to any of these questions, study the water source carefully and analyze the water if possible. Generally, these conditions will make water unacceptable to the users and the source must either be treated or abandoned for a new one.

Filtration Technologies for Small Community Water Supplies

by

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INTRODUCTION

There exist numerous high technology systems to purify water. But a very large portion of people in the developing world live in the rural areas where such systems would be inappropriate or too expensive. Several outbreaks of waterborne diseases have shown that the practice of providing chlorination alone is not sufficient for assuring a high quality of water. Therefore, different features involved in achieving a safe water supply should be carefully studied before general solutions are proposed.

Filtration is an age old technique which has attained a lot of sophistication nowadays. But due to the involvement of cost, sophisticated equipment, and relatively high-skilled personnel, such techniques have not been used in remote areas in developing countries. The rural populations of certain developing countries adopt some techniques with a low level of mechanization to suit their own situations. These are known as traditional methods of treatment. Some of them are listed overleaf:

1. Filtration through winnowing sieve (used widely in Mali).

2. Filtration through cloth (commonly used in villages in India, Mali and the southern part of Niger).

3. Filtration through clay vessels (used in Egypt).

4. Filtration through plant material (commonly used in Kerala, India).

5. Jemping Stone filter method (used in Bali, Indonesia).

Even though these traditional methods are expedient and can remove certain types of particles in water, they do not provide water necessarily of drinking quality. Therefore, it is advisable to add disinfectants so that these methods will yield at least water free from pathogens.

The supply of safe drinking water in a short period is a difficult task in practice. Increasing population, and thus the demand for water and investment in water treatment in developing countries, led to the development of some simple and low cost household water treatment methods applicable in rural areas. Some of these household techniques include:

1. Filtration and syphoning techniques

2. Water coagulation and sand filtration

3. Water filter canister

4. Household slow sand filtration units (India & Thailand)

But household water treatment units should not be considered as the ultimate solution as most of the rural people cannot afford them or have sufficient awareness to adopt them. Therefore, attention has to be given to the successful design of community level plants.

Quality of Water

The most important criteria on which the water treatment alternative is based, is the water quality. Potable water must have a level of constituents which does not cause a health hazard or impair its usefulness to the consumer. Water should be:

- free from pathogens
- clear (i.e., low turbidity; little colour)
- free from offensive taste
- not saline
- free from compounds that may have adverse effects on human health
- free from chemicals which may cause corrosion of water supply system or staining clothes washed in it.

Water quality is vital for determining the degree of treatment required and for selecting suitable treatment processes. In the developing countries, the major problem with the raw water source is turbidity, mainly consisting of clay and suspended silt. On the basis of the two most influential parameters, turbidity and bacteriological content (measured usually is terms of coli content), a guide is presented in Table 1 which gives a procedure for the selection of treatment options for water of different quality.

Table I. Guidelines for Selecting Treatment Options

Water Quality	Treatment
Turbidity <1 NTU E-Coli MPN <10/100 ml	Distribution without treatment
Turbidity 10-50 NTU E-Coli 10-1000/100 ml	Slow Sand Filtration + Chlorination
Turbidity (50-100) NTU	Pretreatment + Slow Sand Filtration + Chlorination
Turbidity up to 150 NTU	Pretreatment (HFP) + Slow Sand Filter + Chlorination
Turbidity >1000 NTU	Chemical coagulation + Sedimentation + Slow Sand Filter + Chlorination

Treatment Options

In the developing countries, treatment systems need to be built and maintained using local resources and technology. Therefore, when designing a water treatment system for a rural population the following factors should be taken into account:

1. Minimum equipment
2. Maximum possibility of using gravity systems
3. Minimum use of chemicals
4. Minimum maintenance and operation
5. Capability of operating with unskilled manpower
6. Construction with locally available materials
7. Minimum cost, including construction, operation and maintenance
8. Acceptability and support by the local community.

Based on these criteria, the slow sand filter appears to be an attractive treatment method. However, the slow sand filter alone cannot be used for high turbidity waters. Surface water in most of the developing countries is fairly turbid, and in this case, pretreatment is necessary if a slow sand filter is to be used. In some cases, alternative filtration methods using locally available materials can be used. This chapter, therefore intends to highlight these filtration techniques by emphasizing their design criteria, adoptability to local conditions, advantages and disadvantages. The application status with cost data are also presented.

Slow Sand Filter

In rural areas, especially in developing countries where land is plentiful, the slow sand filter can be used with success if the raw water is not highly turbid. It is well suited for turbidities less than 50 NTU. In case of highly turbid water, one has to have pre-treatment prior to slow sand filtration. The schematic diagram of a simplified slow sand filtration plant, serving 1,500-20,000 people, is presented in Fig. 1.

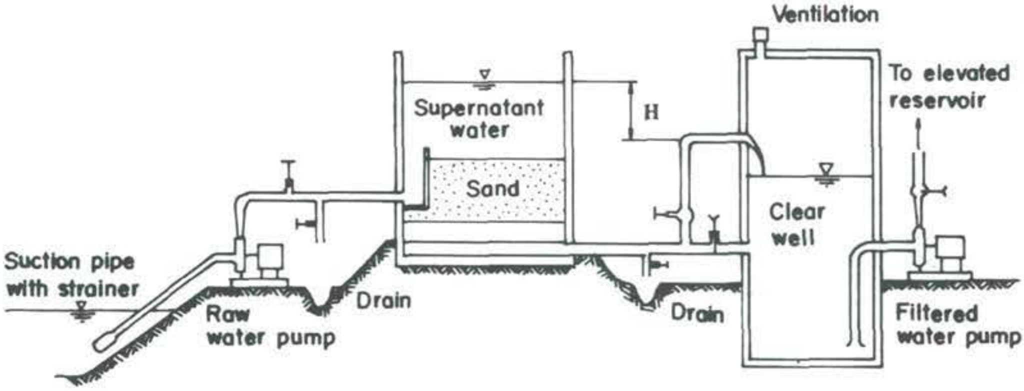

Figure 1. Simplified operation of slow sand filter
(Huisman, 1978)

Principle and Operation

Water is purified by passing it through a bed of fine sand at low velocities (0.1-0.3 $m^3/m^2.h$), which causes the retention of suspended matter in the upper 0.5-2 cm of the filter bed. By scraping out this top layer, the filter is cleaned and restored to its original capacity. The interval between two successive cleanings varies from a few weeks to a few months, depending on the raw water characteristics.

The removal mechanisms of particles in a slow sand filter include mechanical straining, sedimentation, diffusion and chemical and biological oxidation. Coarse and fine particles of suspended matter are deposited at the surface of the filter bed by the action of mechanical straining and sedimentation respectively, while colloidal and dissolved impurities are removed by the action of diffusion. By chemical and bilogical oxidation, the deposited organic matter is converted into inorganic solids and discharged with filter effluent. Microbial and biochemical processes, and hence the removal of impurities, take place chiefly in the top zoological layer of the filter bed (the "Schmutzdecke').

The important design parameters in slow sand filter are the depth of the filter bed, filter media size, the filtration rate, and the depth of the supernatant water level. As far as possible, these design parameters should be based on experience obtained with existing treatment plants which use a water source of similar quality. In the absence of reliable data from existing treatment plants, pilot plants can be used to determine suitable design criteria. The values presented in Table 2 can serve as helpful guidelines.

Table 2. Design Summary of Slow Sand Filter

Design parameters	Range of values
Filtration rate	0.15 $m^3/m^2.h$ (0.1-0.2 $m^3/m^2.h$)
Area per filter bed	10-100 m^2 (depends on the filter construction)
Number of filter beds	Minimum of 2
Depth of filter bed	1 m (1-1.4 m)
Filter media size	Effective size (e) = 0.15-0.35 mm Uniformity Coefficient (U.C.)= (2-5)
Height of supernatant water	1 m (1-1.5 m)
Underdrain system:	
- Standard bricks - Precast concrete slabs - Precast concrete blocks with holes on the top - Porous concrete	Generally no need for further hydraulic calculations
- Perforated pipes (laterals and manifold type)	Maximum velocity in the manifolds and in laterals = 0.3 m/s Spacing between laterals = 1.5 m Spacing of holes in laterals = 0.15 m Size of holes in laterals = 3 mm

Since the purification mechanism in a slow sand filter is essentially a biological process, its efficiency depends upon a balanced biological community in the zoological film, the "Schmutzdecke". Therefore, it is desirable to design the filters, to operate as far as possible, at a constant rate. However, the operation of slow sand filters in most developing countries is intermittent due to the financial difficulties in employing operators to run the plants round the clock. But the intermittent operation causes deterioration in effluent quality because during stoppages the microorganisms causing bacteriological degradation of trapped impurities lose their effectiveness. Intermittent operation disturbs the continuity needed for efficient biological activity.

One way of overcoming this problem is by allowing the filter to operate at a declining rate after a cycle of constant rate filtration. Declining rate filtration gives an aditional water production of 0.5 and 0.7 $m^3/m^2.h$ with a declining rate operation for 8 and 16 hours after 16 and 8 hours of constant rate operation respectively. The effluent achieved during this operation is generally satisfactory. Moreover, the declining-rate mode may be applied during night time, resulting in significant savings of labour.

Advantages and Disadvantages

Simplicity of design and operation and minimal requirements of power and expensive chemicals make it an appropriate technique for the removal of organic and inorganic suspended matter as well as pathogenic organisms present in surface waters of rural areas in developing countries. Sludge handling problems are also minimal. Close control by an operator is not necessary which is important to small communities because an operator may have several responsibilities. Design experience in America shows that the slow sand filter is more than 99.9 percent efficient in removing *Giardia* cysts and coliform bacteria, and provides a stable effluent quality with a low operating budget (Seelaus, T. J., et al., 1986). It has the added advantage of being able to make use of locally available materials and labour.

A cost estimate (Paramasivam et al.,) based on 1979 prices (in Nagpur, India and excluding the contractor's profit) has shown that the filter bed cost per m^2 is Rs. 350 (US$ 43.75), and the cost per meter of wall length is Rs.570 (US$ 71.25). Another study (Paramasivam *et al.*, 1981) indicates that there is no significant cost penalty for building more than 2 filters for gaining reliability and flexibility in operation. The study revealed that the number of filters can be raised from 2 to 5 by spending roughly 6 to 22% more money.

However, slow sand filtration has certain limitations. The requirements of a large area and large quantities of filter medium and labour for the manual cleaning are the major disadvantages. These limitations do not apply to rural areas in the developing world where land and unskilled labour is available.

Appropriate Pre-Treatment Methods for Rural Communities

Experience with the operation of slow sand filters shows that, when the average turbidity of raw water exceeds 50 NTU, some form of pre-treatment is necessary for the smooth operation of a slow sand filter. Some of the simplest and most appropriate pre-treatment systems are as follows:

1. River bed filtration
2. Storage in storage basins
3. Plain sedimentation
4. Rapid roughing filtration (coconut fibre filters)
5. Horizontal-flow coarse-media filtration
6. Gravel upflow prefilter.

This chapter, however, discusses only the prefiltration techniques, which can be used as pretreatment methods.

Horizontal-Flow Coarse-Media Filtration

This is essentially a prefiltration technique which uses coarse gravel or crushed stones as filter media and is highly suited for turbid waters with turbidities greater than 50 NTU. A com-

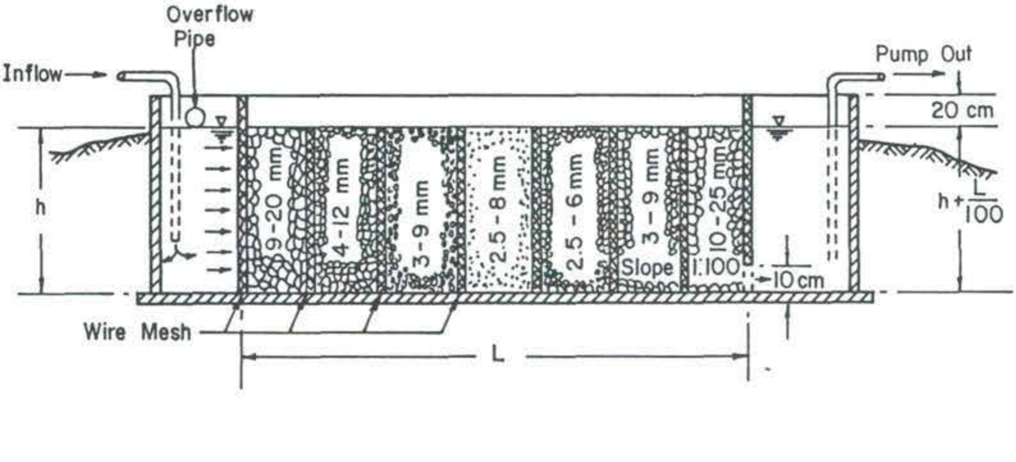

Figure 2 Horizontal-flow coarse-media filter

bination of filtration and sedimentation of suspended solids take place during the horizontal passage of water through a coarse-fine-coarse filter bed. At the same time, biological mechanisms similar to those in slow sand filtration help to remove pathogens, although in a limited quantity. Research at the Asian Institute of Technology (Thanh & Ouano, 1977; Thanh, 1978) has indicated that the unit can account for 60-70% of turbidity removal and about 80% of coliform removal. But if the inlet and outlet compartments are exposed to sunlight, there may be algal growth. This can be prevented by having a cover against the sunlight. The filter arrangement is given in Fig. 2 and its design criteria in Table 3.

This filter can be successfully used as a pre-treatment unit to waters with a turbidity range of (50-150) NTU. The prefilter unit has been successfully applied to a village water supply scheme in Thailand, in Jedee-Thong Village (Thanh et al., 1978), to pretreat raw water prior to the application of slow sand filtration for the potable water supply to approximately 720 residents. Table 4 summarizes the performance of the system. Several full-scale systems of this type have been operating in rural Thailand for some years without any trouble (Thanh & Hettiaratchi, 1982).

Table 3. Design Summary of Horizontal-Flow Pre-Filter

Parameter	Range of values
Filtration rate	0.3-1.0 $m^3/m^2.h$
Optimum filtration rate	0.5 $m^3/m^2.h$ for low turbid waters (15-50 NTU)
	0.3 $m^3/m^2.h$ for high turbid waters (up to 150 NTU)
Depth of filter bed	1 m (0.8-1.5 m)
- water level	0.8 m
- free board	0.2 m
Length of the filter	5 m (4-10m)
Length:width ratio	1:1 to 6:1
Area of the filter	10-100 m^2
Specification of filter bed	9-20 mm gravel
(in the direction of flow)	4-12 mm gravel
	3-9 mm gravel
	2.5-8 mm gravel
	2.5-6 mm gravel
	3-9 mm gravel
	10-25 mm gravel
Slope at the bottom	A slope of 1/100 is provided towards the effluent end to facilitate the flow of pretreated water
Covering of inlet and outlet compartments	This is made if the filter is exposed to sunlight

The cost of one m^3 of treated water is approximately US$ 5 according to 1978 prices in Thailand, which is quite reasonable as far as rural supply is concerned (Thanh, 1978).

Although the construction and operation and maintenance of horizontal-flow prefilters is simple, land requirements are high (even higher than slow sand filters).

Table 4. Performance of Horizontal Pre-Filter and Slow Sand Filter in Jedee Thong Village Water Treatment Plant, Thailand

System	Turbidity (JTU)		Total coliform (MPN/100 ml)		Head Loss, Development (cm/day)	Filter Run
	Influent (average)	Effluent (average)	Influent (average)	Effluent (average)		
Horizontal Pre-filter	25	12	5000	1000	0.6	
Slow Sand Filter	12	3	1000	100	0.5	More than five months

Upflow Gravel Prefilter

This filter is differentiated from other filtration techniques by the direction of the flow of raw water. Water is distributed to the prefilter in an upward direction through the perforations of the underdrain system. Several gravel layers ranging from coarse gravel layers at the bottom to successively fine gravel layers are packed to a total height of 1 m. The height could be altered according to the need. The gravel size selection should be based on the local availability of the gravel and degree of pretreatment necessary. Filter underdrains can be fabricated locally, using either a 'Teepee' (Anboleda, 1973) type of design or a manifold and lateral system.

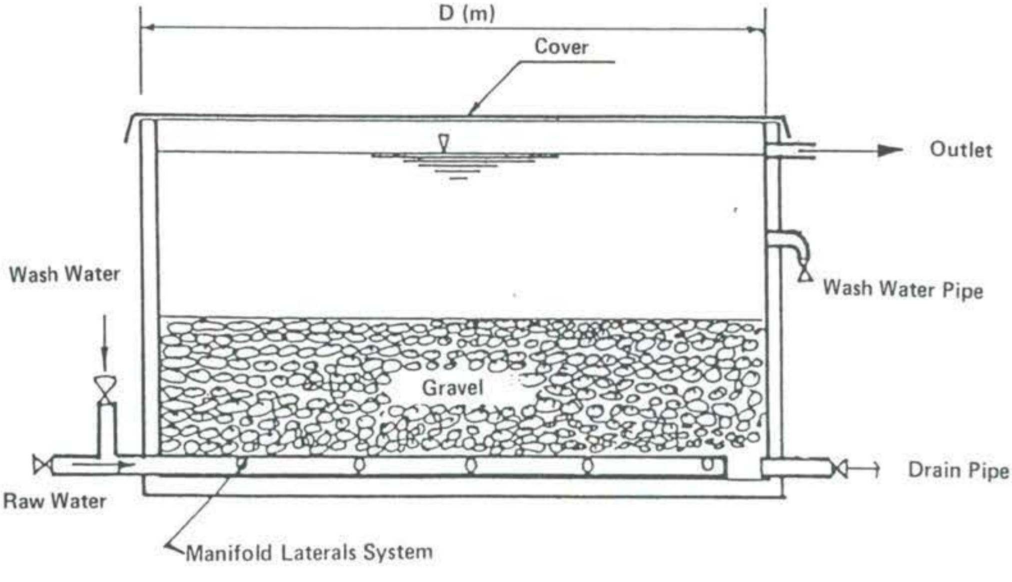

Fig. 3 Important components of upflow gravel prefilter

The filtration rate in gravel upflow filters is relatively high because of the large pore spaces that are not likely to clog rapidly. The frequency of cleaning can be as low as once a month depending on the quality of raw water. The cleaning is achieved by flushing water at high velocity in an upward direction. Design criteria are given in Table 5 and a typical upflow gravel prefilter is schematized in Fig.3.

Table 5. Design Summary of Upflow Gravel Prefilter

Design Parameters	Range of values
Filtration velocity ($m^3/m^2.h$)	2 to 6 (depending on the quality of water)
Depth of gravel bed (m)	0.7 to 1.2
Gravel size (cm)	1.5-3 mm to a height of 10-20 cm 3-4 mm to a height of 10-20 cm 4-6 mm to a height of 20-30 cm 6-10 mm to a height of 30-50 cm
Effluent feed system (manifold - lateral system)	laterals = 50 mm diameter galvanized steel pipe with 4 mm holes at 30 cm distance apart lateral spacing = 1.5 m apart manifold = 150 mm x 150 mm concrete channels

Alternative Technologies

Instead of a slow sand filter, one could also use other filtration technologies which have been proved to be economical and successful in providing water of drinkable quality. Two of them are discussed below in brief.

Two Stage Filter

Two stage filters using coconut fiber and burnt rice husk as media were developed by Frankel (1977, 1979). A small unit built at Ban Som, Thailand, is given in Fig. 4. The filter is effective in treating waters with turbidities as high as 150 NTU (Frankel, 1979).

It consists of two stages, a first stage of shredded coconut fiber roughing filter, to remove coarse materials, and a subsequent burnt rice husk polishing filter to remove the residual turbidity and other contaminants. This fiber was found to remove particulate materials as well as some dissolved matter effectively due to the absorption phenomenon of burnt rice husk. The design criteria are given in Table 6.

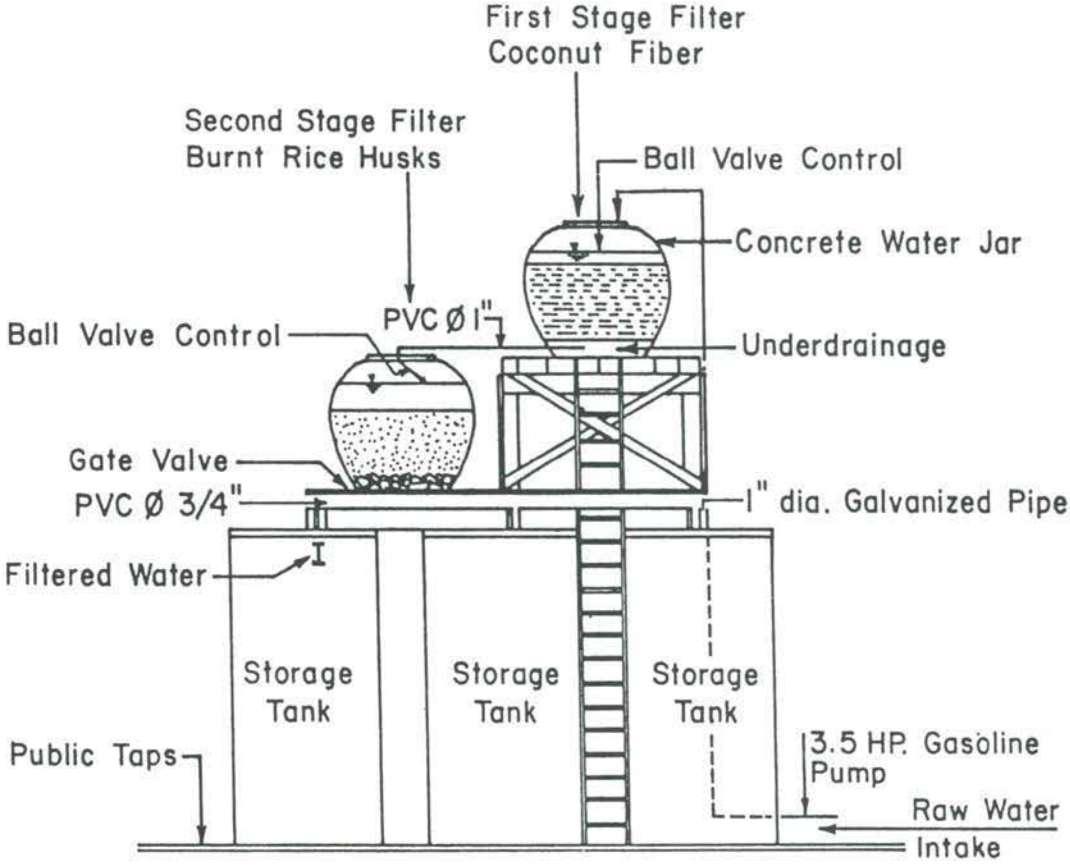

Figure 4. Two-stage filtration unit constructed at Ban Som, Korat, Thailand

Instead of separate two-stage filtration, burned rice husk and coconut fiber can be combined into a single-stage, dual-media, filtration unit which in terms of filter run is more economic and effective than the series filtration (Thanh & Pescod, 1976).

Operation

Shredded coconut fiber can be prepared by soaking the husk for 2-3 days in water, then shredded by pulling off the fibers one by one and removing the solid impurities which bind the fibers. Partially burned rice husk after being sieved through a one-eighth of-an-inch mesh wire screen (or mosquito net) is put in water and mixed, then the supernatant water with fine ashes is discarded. This washing procedure is repeated several times.

When the headloss exceeds the depth of free board, the filter run is stopped and the used coconut fiber is rinsed properly with clean water for reuse or is replaced with new coconut fiber.

In case of burned rice husk filter, the top 10 cm of the medium is scraped off and the operation is restarted for a new cycle. In both filters, filter washing takes place once in every three to four months depending on the turbidity of the raw water.

Table 6. Design Summary of Two-Stage Filtration

Parameter	Coconut Fibre Filter (1st stage filter)	Burnt Rice Husk Filter (2nd stage filter)
Filter depth	60-80 cm	60-80 cm
Freeboard	1.0 m	1.0 m
Filtration rate	1.2-1.5 $m^3/m^2.h$	1.2-1.5 $m^3/m^2.h$
Underdrain system		
i) Gravel layer (supporting media)	Pea gravel of 1/8 to 1/4 inch (5 to 10 cm depth)	
ii) Lateral, manifold underdrain system	Main drain and lateral pipe material: G.I. or PVC pipes Spacing between orifice: 0.3 m Spacing between laterals: 0.3 m Diameter of orifice: 0.6 cm Ratio of area of orifice to lateral: 1:2 Ratio of area of lateral to main drain:1:1.5	

Advantages and Disadvantages

It is very cost effective and can handle high turbidities. It removes colour and taste due to the absorption capacity of burned rice husk. This two-stage process operates at a filtration rate 10-15 times higher than in slow sand filters, thus reducing the construction costs considerably.

Pilot plants were operated during 1973-1974 in Cambodia, Laos, Thailand and Vietnam. Some larger units that have been built in Philippines perform consistently well, with an average of 90% removal of coliforms. Experience in Southeast Asia indicates that the total construction cost of the system serving a population of 2,000 was less than US$2 per capita (Frank, 1979).

The major problem is that in most cases bacteriological removal is insufficient, which may not satisfy the WHO drinking water standard in terms of coliform count. However, in places where sand is not available to use in conventional filtration, this system could well be the only choice.

Sea Water Supply (SWS) Filter System

This filter system was developed in the United Kingdom which applies the concept of using the river bed itself as an efficient natural filter. The schemetic diagram of the unit is shown in Fig. 5.

Operation

The operation is quite simple. A non-corrosive box with a cross section of about 60 cm x 60 cm is buried under the river or stream bed upside down, as shown in Fig. 5. About three-

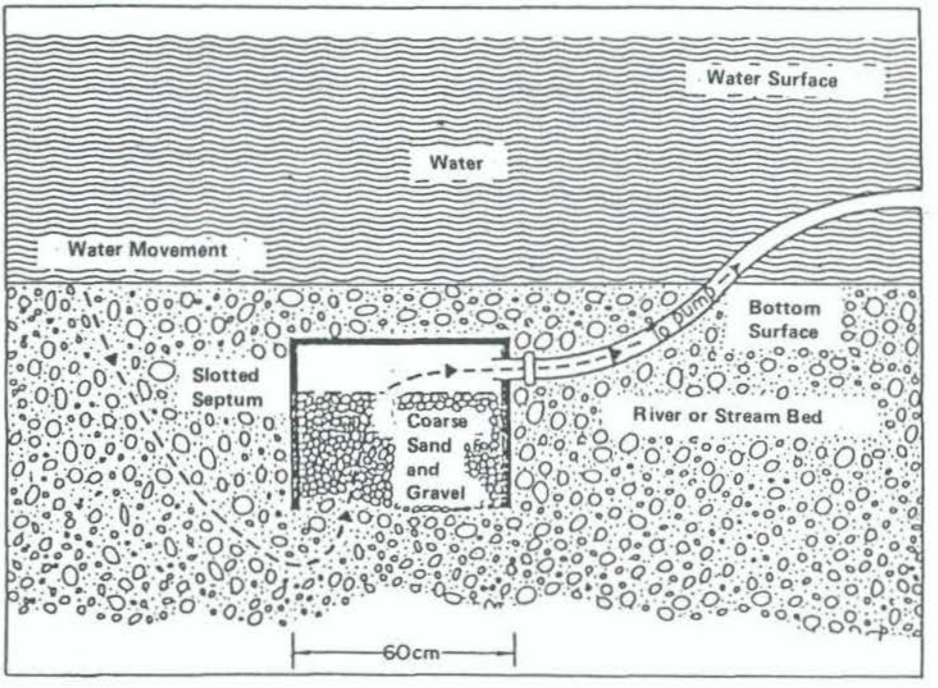

Figure 5. The SWS water filtration system
(Cansdale, 1979)

quarters of the box is filled with coarse sand and gravel and the upper quarter of the box is left empty. A clearance of at least 15 cm is provided to the top of the box as installed from the river bed. A flexible tube connects the empty space of the box to a suction pump off-shore, as shown. When the pump is switched on, it creates a suction head in the empty space which in turn facilitates the seepage of water through the river bed and reaches the filter medium of the unit. The design criteria for a typical filter unit is given in Table 7.

This filter system is being used in Malaysia, the Philippines, Singapore and Thailand to supply water for fish farming, swimming pools, industrial use, etc. (Vigneswaran & Viswanathan, 1983). It could also be used as a prefilter unit to reduce load on the subsequent treatment unit. It has also been used successfully to treat the highly turbid waters of the River Ganges in India (Nigam, 1981). Recently a modified version of the SWS unit has been making an important contribution to disease control in Sudan (Anon, 1983).

It is a simple process with no moving parts and chemicals. Continuous as well as intermittent operations are possible. Installation takes hardly one hour for a river bed unit. However, it is applicable to permanent surface water sources only and cannot be used in deep muddy beds, steep rocky shores and gorges.

The system is remarkably low in cost. For a large unit with an output of 40,000 L/h, it was reported that the total cost over a period of 5 years was only UK£ 360 according to 1979 prices. This corresponds to 20 pence/day, including 1 pence per 5,000 liters for electricity and 5 pence for petrol (Cansdale, 1979).

Table 7. Design Summary of SWS Filter System

Parameter	Range of Values
Unit	i) Square shaped box of 60 x 60 cm (maximum) with depth of 40 cm ii) A hollow section of 10 cm between the top portion of the media to the roof of the box. This hollow section has a series of distance pieces to give stability and to stop collapse of the unit under vacuum.
Filter bed media	Coarse sand and gravel of size between 0.5 to 5.0 mm can be used. Both very fine sand, especially of wind-blown origin (0.2 mm), and very large stones (50 mm) are not suitable as filter media.
Suction head	Maximum allowable total suction head should be kept below 7 m.
Delivery line	- Flexible armoured hose is needed from the unit to at least the highest water level. - Semi-rigid PVC pipes can be used from the river edge and also for the delivery line.
Pumps	Handpump with 4 m^3/h.

Comparison Between Different Methods of Filtration

The tables on the following pages compare different filtration techniques, which can be used as a guideline in selection of the appropriate technique for a given raw water.

Package Designs

Package treatments plants are usually designed for smaller installation with prefabricated units which offer cost savings over conventional plants. These are suitable for places where on-site construction and assembly are impracticable. Upflow-downflow filtration is a simple and economical treatment method for small community water supply in developing countries. It could be used in the design of simple modular and package water treatment plants. Again it could be seen that a single unit replaces three separate units of a conventional process thus making the plant less cumbersome to build and operate.

Upflow-Downflow Filtration

Upflow-downflow filtration includes the conventional mixing, flocculation, sedimentation and rapid filtration in one unit. The system contains a battery of cells as shown in Fig. 6.

The system here consists of a gravel bed flocculator with downflow, tube settlers with upflow and a dual media filter with downflow. These units, in effect, produce rapid mixing, flocculation, sedimentation and filtration. In the gravel bed flocculator a packed bed of gravel provides an ideal condition for the formation of compact settleable flocs because of continuous recontacts provided by the sinous flow of water through the interstices formed by the gravel. The direction of flow can be either upward or downward.

Table 8. General Features of Alternative Filtration Options for Small Community Water Supplies

Parameter	Slow Sand Filtration	Two-Stage Filtration	SWS Filtration	Horizontal Flow Pre-Filter
Raw water requirement	50 NTU	150 NTU	Can be used even in highly turbid waters	200 NTU
Extent of treatment	Produces good quality of water in terms of turbidity and bacteriological contents.	Produces good quality of water in terms of turbidity and bacteriological contents.	Used as pre-treatment unit	Used as pre-treatment unit
Pre-treatment	If raw water turbidity is greater than 50 NTU, a pre-treatment unit such as horizontal flow filter is needed.	If raw water turbidity is greater than 150 NTU, a multi-stage unit or coagulation step is necessary	—	—
Post treatment	Preferably disinfection	Preferably disinfection	Depends on raw water quality (generally slow sand filter followed by disinfection)	Depends on raw water quality (generally slow sand filter followed by disinfection)
Filtration rate	0.1-0.2$m^3/m^2.h$	1.2-1.5$m^3/m^2.h$	—	—

Table 8. (continued)

Parameter	Slow Sand Filtration	Two-Stage Filtration	SWS Filtration	Horizontal Flow Pre-Filter
Filter media size	Sand (e) = 0.15-0.35 mm, U.C. = 2-5	Coconut fibre, shredded and washed. Burned rice husks of e = 0.3-0.5 m and U.C. = 2.3-2.6	Course sand and gravel of size between 0.5 to 5 mm can be used	Gravel 9-20 mm 4-12 mm 3-9 mm 2.5-8 mm 2.5-6 mm 3-9 mm 10-25 mm
Filter media depth	1-1.4 m	0.6-0.8 m	0.3 m	0.8 m
Underdrain system	Lateral manifold system (for small filter units) or standard bricks or precast concrete blocks with holes in the top or porous concrete (This underdrain system is under supporting gravel layer)	Lateral manifold system under the supporting gravel layer.	—	—
Supernatant level	1-1.5 m	1.0 m	0.1 m	—

Table 8. (continued)

Parameter	Slow Sand Filtration	Two-Stage Filtration	SWS Filtration	Horizontal Flow Pre-Filter
Cleaning procedure	Scrape out the top few centimetres and replace with new sand (or the sand is washed and replaced)	Used coconut filter is replaced with new (or washed) coconut fiber material. In the case of burnt rice husk, top 10 cm is scraped off and replaced with new media	—	Cleaning is done periodically, compartment by compartment Gravel in the particular compartment is taken out, cleaned and replaced
Cleaning Frequency	Once every 2 months (depends on raw water quality)	Once every 3 or 4 months (depends on raw water quality)	—	Once in 2-5 years (depends on raw water quality)
Construction:				
(i) Cost of construction	Average (if the appropriate sand size is available)	Low	Low	Average
ii) Land requirement	Large	Average	Small	Large
iii) Materials for construction	(i) Concrete (ii) Ferrocement (iii) Reinforced concrete	Wooden support structure, concrete or G.I. jars for filter tank	Rectangular fiber-glass box of 0.6 x 0.6 x 0.4 m	(i) Brick work (ii) Ferrocement (iii) Reinforced concrete
iv) Construction	Less difficult	Simple	Simple	Less difficult

Table 8. (continued)

Parameter	Slow Sand Filtration	Two-Stage Filtration	SWS Filtration	Horizontal Flow Pre-Filter
Operation (i) Skilled operator requirement	No	No	No	No
(ii) Ease of operation	Simple	Very simple	Very simple	Simple
Maintenance cost	Average	Low	Low	Average
Special requirement	None	None	Near the river or water source	None
Size of community per unit	Medium population	Less than 1,000 people	Large unit (with an output up to 40,000 1/h)	Medium population

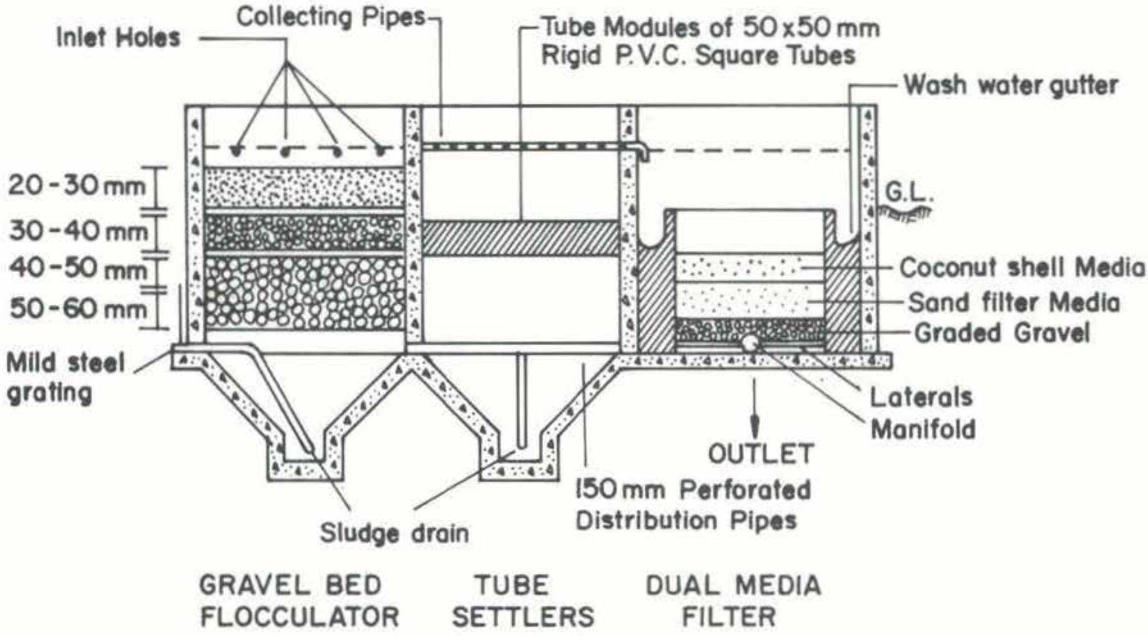

Figure 6. Flow diagram and ground-level view of upflow-downflow plant in Varangaon (Schulz & Okun, 1984)

The basic concepts of tube settlers are the same as that for conventional sedimentation basins. But in tube settlers, the surface area is increased by the division of the basin by horizontal plates into several compartments on top of each other. When installed in a conventional sedimentation basin, these units are found to improve its capacity by 50 to 150%. The most common tube settling devices used in the developed countries are inlined tubes, circular or rectangular in section, packed and fabricated to form a module.

Dual media filters conventionally consist of sand and anthracite but the media may vary from plant to plant depending on what is available locally. In effect, the raw water with coagulant get mixed and flocculated in a gravel bed flocculator, clarified through a clarifier, filtered through the dual media filter and produces effluent for disinfection. It must be noted that the entire treatment train is incorporated in one unit. Depending on the raw water quality and the flow rate, the number of such treatment units may be increased: either or all of the three units may be increased in number.

The choice of filter depends on experience, but a typical design is given in Fig.6. Some typical design values are given in Table 9. Several applications of upflow-downflow filters in rural communities are available in developing countries. Extensive use in India has been reported by Kardile (1981). For example, a 2,400 m^3/day plant for Ramtek (Population of 20,000), for treating low turbidity water; a 1,000 m^3/day plant for Chandori (population of 15,000), and a 4,200 m^3/day plant for Varangaon (population 35,000), were designed for the treatment of turbid waters.

Both the plants at Ramtek and Chandori were built using locally available materials such as bricks. It was also found that the construction costs of these plants were only 30 to 50% of the construction costs of conventional plants with the same capacity (Kardile, 1981).

Table 9. Typical Design Values of Upflow-Downflow Filters
(Shulz & Okun, 1984)

Parameter	Unit	Value
Capacity (flow)	m^3/d	100-2400
Raw water turbidity	NTU	0-160
Raw water colour	Pt - Co units	0-180
Filter depth	m	1.5-3.0
Filter media (effective size)	mm	0.7-2.0
Filtration rate	m/hr	12-16
Gravel bed size	mm	10-60
Gravel bed flow rate	m/h	4-8
Time of single filter run	h	10-45
Washwater consumption	% of water treated	1.4-2.9

Upflow-downflow filters can be constructed totally with locally available materials. They can treat waters with initial turbidities of 10-200 NTU satisfactorily. However experience is still limited to a few countries only and hence may need pilot scale studies.

Conclusions

Filtration technologies that have been discussed so far are the most economically promising options to the rural communities in developing countries. Water purification plants using these kinds of design can be built with entirely local know-how and materials, thus could be cheaper than the conventional methods. But it is to be mentioned that the technologies discussed here are based on experiences in a particular situation and provide only some basic information. Therefore, for designing a complete treatment unit for a particular community, proper modifications of the design criteria should be made to best suit the local situation.

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ENVIRONMENTAL MANAGEMENT MACHINERY

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"When the process of development is such that it takes account also of the effects on the environment and thus provides for well-being and viability in a sustained manner, it constitutes management of the environment." United Nations Environment Programme Governing Council, 1975.

INTRODUCTION

This chapter addresses certain management and institutional aspects pertinent to considerations of the environment in development planning. Over the past twenty years or more, the environmental problems experienced throughout the world have forced both developed and developing countries to question and reassess their methods of planning and administration. Recognising the importance and relevance of these issues to social, economic and political considerations in policy decision-making in each country, an attempt is made to examine the rationale behind the management of the environment; why environmental management matters; what comprises that management and how it can be achieved; what models exist and the interactions between the appropriate agencies.

The areas concerned include the administrative and organisational structures in environmental decision-making; the interactions between government bodies, industry, and public action groups; the linkage mechanisms between government ministries, departments and agencies, and how action is co-ordinated. Legislative back-up and the identification of sanctions on environmental transgressors are considered essential, along with the required support systems for training, promotion, funding, monitoring and environmental assessment procedures.

Rationale behind the Management of the Environment

Since the United Nations Conference on the Human Environment in Stockholm in 1972, and the follow-up Conference on Human Settlements at Vancouver in 1976, concern for the environment has grown and become a global issue. Most governments have acknowledged it as an issue of importance to themselves, and have taken action to establish environmental policies and management machinery to implement them.

The Stockholm Conference gave credence and importance to the continuing environmental and ecological movement, and made clear that the most acute environmental problems of the developing world arise from poverty and inadequate development. The way ahead to a better quality of life was through the integration of the environment with population and resources within the framework of the development process itself.

The purpose of the Vancouver Conference was to promote action to precipitate policies. It was basically concerned with physical planning and organisational arrangement and provided an opportunity for world governments to join in a commitment to improve the quality of human settlements; to contribute to the creation of better international arrangements for effective action; and to exchange information. Among other issues, attention was drawn to the shortcomings and limitations of national development plans based almost entirely on economic or financial criteria. It stressed the need to consider the physical and spatial aspects of development in the preparation of national plans.

As a result of the two Conferences and the commitments made by the various governments, there has been a continuing and growing activity by both developed and developing countries in the need for sound management of their natural resource base of soil, water, forests, fish and other wildlife together with an integrated approach to the planning and management of the natural and human environment. The success of this integration is clearly dependent on the availability and distribution of financial and human resources for development and the choices made between alternatives which are the least damaging to the environment.

The Stockholm and Vancouver Conferences provided the initial rationale for the effective management of the environment by identifying the physical, economic, social and institutional relationships between human settlements and the natural environment, and a way to deal with environmental issues that arise at national, regional and local levels. The relationships betwen environmental management, environmental assessment and supporting measures were identified (Figure l), and provided a basis for focussing attention on specific issues and needs for action. In recent years, considerable international research and practical experience has been gained by governments and agencies in the use of environmental impact assessment (EIA) and environmental management techniques which are now well established in a number of countries.

ENVIRONMENTAL ASSESSMENT	ENVIRONMENTAL MANAGEMENT
Evaluation and Review Research and Monitoring Information Exchange	Goal Setting and Planning International Consultation and Agreements
SUPPORTING MEASURES	
Education and Training Public Information Technical Co-operation	Organisation Financing Legislation

Figure 1. Simplified scheme of relationships between Environmental Management, Environmental Assessment and Supporting Measures

International organisations and agencies have also been engaged in developing general principles applicable to major problems of marine and atmospheric pollution across national frontiers and of the 'Global Commons'. Much of this work has been directed towards the establishment of administrative organisations to manage the shared resources jointly, including the control of pollution, rather than to provide legal means of obtaining redress for damage caused by misuse.

The Meaning of Environmental Management

One of the problems which has bedevilled the development of management techniques and machinery in relation to environmental considerations in recent years has been the proliferation of new terms or phrases and the ever widening environmental interests. The need to clarify the phrase 'Environmental Management' is of prime importance. In essence, 'Environmental Management' provides for the co-ordination of actions and policies of government and/or agencies which jointly produce or effect an improvement in the natural and man-made environment. This cannot be fully effective unless it is informed by broader and longer-term planning intentions, whether expressed in national, regional or local plans and policies.

Why Environmental Management Matters

The concept of 'Environmental Management' and the need for it in developed and developing countries has been recognised for many years. The development of a coherent system of environmental law at national level, and the establishment of administrative organisations as a means of environmental control, is a step in the direction of overcoming past omissions, and as a way of planning the resources as a whole. In this way, the evaluation of alternative policies can be made in a more informed, and systematic manner by defining objectives and targets, by measuring needs and output, and by reviewing alternatives. Environmental management is also an aid tò the political process in that political will can be more clearly specified and implemented. Equally, it is an approach which seeks to serve the needs of society as a whole rather than on a fragmented basis.

What Comprises Environmental Management

One of the most obvious patterns in the development of environmental management and protection is the increased responsibility shown by governments in enacting environmental legislation, and in the establishment of administrative structures including Environmental Protection Boards, special Councils or Agencies with support staff, as separate bodies or within existing government ministries and departments. This approach allows more uniform regulations and control; the finding of appropriate solutions to problems within different administrative jurisdictions; the issue of central advice and guidance; and the assurance of a national commitment to environmental problems.

While conditions prevailing in different countries are varied, environmental management concerns may be classified under a number of general headings such as, population growth; depletion and deterioration of natural resources; urbanisation and industrialisation; pollution control (air, water, land); and other forms of environmental disturbance. These topics are usually intertwined and present complex management problems in dealing with the interaction between population and the environment, on the one hand, and in the efficient use of resources, on the other.

As resources dwindle in rural areas, for example, the attraction of larger urban areas becomes greater for rural people. This in turn, becomes a source of social and political tensions which require careful management and understanding by all concerned. Both the rural and urban sectors face the same fundamental environmental problems which interact with each other. While there are no easy solutions, there is still a tendency to deal with them seperately in a piecemeal and *ad hoc* manner, rather than applying corporate management methods and techniques.

Where serious problems of environmental deterioration and resource mis-management occur, remedial action requires the combined support of the political process and backing of management services in the formulation and implementation of appropriate policies, programmes and action. The deterioration of natural resources has considerable consequences for a country's survival and future development potential. To protect and improve these conditions requires the adoption of an integrated and co-ordinated plan of action. The principles embodied in this approach cover a wide range of issues, and deal with the complex inter-relationships between ecological, socio-economic factors and the development process itself.

From available experience in a given country, appropriate strategies to deal with particular problems can be determined and, at the same time, allowances can be made for flexibility in the formulation and implementation of the required policies, programmes and action plans. In line with this approach, considerations relating to both strategies and tactical actions can be grouped in two main areas. The *first*, requires the development of a long-term programme of environmental improvement within the framework of an integrated action plan. The elements of the plan of action require to be formulated at each level of planning (national, regional and sectoral) to cope with specific environmental problems. The *second*, requires different types of action at different levels, ranging from the implementation of specific projects for natural resource development in different ecosystems; the redeployment of industry; management of tourism and leisure in protected areas, to the control of pollution at various levels.

Other areas for consideration are research, the development of planning and management techniques and methods; and the provision of an information and institutional framework within which these activities can operate. The development of methods for integrated planning and management and the application of environmental impact assessment to the analysis of projects and alternatives are essential. In addition, training programmes are required to develop environmental skills as well as the exchange and dissemination of environmental information of all kinds. An essential prerequisite being the creation of machinery to channel action in the appropriate directions.

How Environmental Management can be Achieved

At national levels, the need to consider environmental protection as a necessary element of long-term strategy has resulted in the creation of environmental secretariats at different levels of administrative operation. It is not clear, however, as to the effect, if any, these machineries have had in influencing or changing the attitudes of the traditionally stronger and longer established economic groupings within governments. The establishment of legal frameworks for environmental protection has also been somewhat uneven, and it is not surprising that an acceptable standard form for such a framework, despite the many examples available, has yet to evolve. In a number of developing countries legislation for environmental protection at the national level is still incomplete. This does not universally apply to sectoral environmental legislation dealing with public health matters, labour protection, and municipal by-laws limited to hygiene aspects. Differing political systems and complexities of existing administrative and financing arrangements in most countries, preclude the application of simple formulas to the introduction of a comprehensive environmental management system to all countries.

The organisational forms for environmental management systems have tended to involve direct supervision from a single department at national level, and/or the establishment of a multi-disciplinary agency with or without executive powers. Other arrangements involve the establishment of two or more tiered management structures; designation of sectorial or special area authorities; regional development and district authorities based on appropriate areas of responsibility. These authorities, including municipal areas, may or may not be limited to planning matters. The division of functions and responsibilities between the various organisations are usually based on technical efficiency, administrative effectiveness, political accountability, and fiscal equity.

Introducing a system of environmental protection and management into an existing administrative system needs careful preparation, not just in terms of technical skills required but in the manner in which it is approached. In the early stages, it is essential to keep it simple, and perhaps confine it to the introduction of environmental assessment methods and techniques which are now universally available and well understood. Such an approach should be supported by technical training programmes as may be deemed necessary.

Too much attention is often paid to the intricacies of environmental planning and insufficient thought and trouble taken to determine the best way of introducing it. The most effective system will collapse if introduced too quickly by inexperienced staff, particularly where there is opposition from other department sources. The following seven points may be said to be sound management principles when introducing any new management philosophy. They are:

Commitment

There must be a formal political commitment to establish environmental protection and management in principle.

Decision

Once committed, decisions must be taken as to the responsibilities for implementation, staffing, and the reporting process.

Information

The information stage is all important. Failure to communicate with other interested or affected departments or personnel will inevitably lead to misunderstandings andsubsequent opposition. Those directly involved in the initiation process will require some degree of training depending on experience.

Data Gathering and Interpretation

The collection and interpretation of information is not an end in itself, and should only be done to the extent needed to develop the management system. The importance of paying attention to adequate liaison with third parties cannot be overstressed or emphasised enough.

Planning

Plans prepared within the framework of a comprehensive environmental protection and management system should not be seen as the plans 'conceived by' and 'belonging to' the 'Environmental Boards or Agencies'. They are the environmental service and resource plans for all departments of government.

Agreement

Environmental planning and management must not be too concerned with seeing clever plans written. The plans are only worth writing if they result in policies being agreed and adopted and in resources being committed. Environmental planning and management must seek to ensure that the plans are realistic expressions of political will.

Evaluation

There is a need not only to monitor and update the policies adopted, but to establish the practical value of environmental planning and management itself. The evaluation of environmental planning may be difficult to discern as many benefits, such as changes in attitude, improved co-operation in environmental assessment activities and in the environment generally are intangibles.

A diagrammatic explanation of these stages is shown in Figure 2. It will be seen that the essential step of implementation must remain clearly within the operational control of the organisation appointed to establish an environmental planning system. In this way the environmental organisation and other interested departments of government have complementary, not conflicting roles.

Administrative and Technical Considerations

Administrative and technical procedures for incorporating environmental concerns into the development planning process varies from country to country. The effectiveness of these procedures as management tools are largely dependent on political commitment, organisational

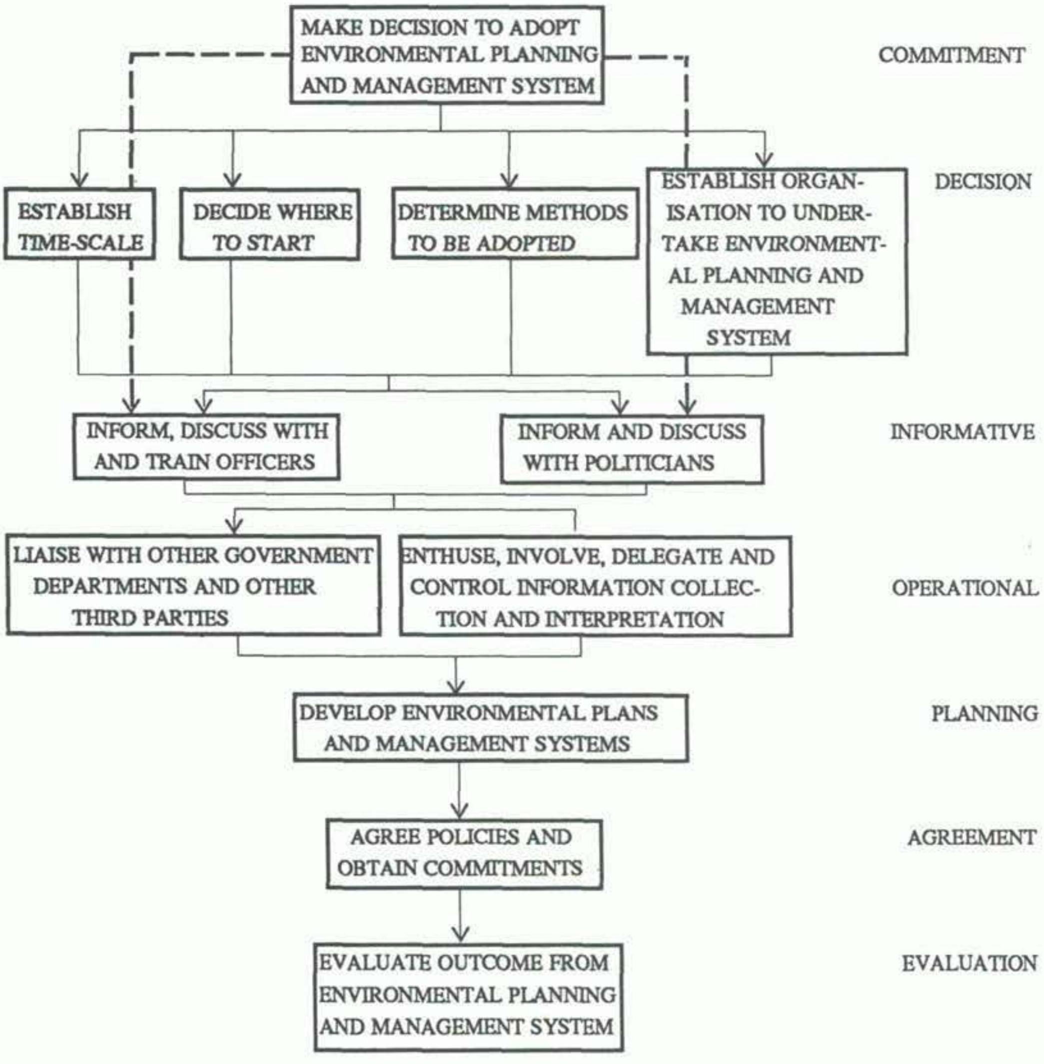


Figure 2. Seven basic stages in introducing an Environmental Planning and Management System

arrangements, and the availability of staff and resources to apply them. At theoretical level, a large number of general and technical guidelines have been produced by international organisations, academic communities, research establishments, and by governments themselves. In general, guidelines provide useful procedural or technical instructions or explanations related to various aspects of the environmental planning and assessment process. In particular countries, guidelines have been produced by government departments or private agencies having a responsibility or interest in ensuring that environmental issues are introduced or taken into account in the decision-making and development plan process. Depending on their purpose, guidelines may be mandatory or advisory.

Guidelines may incorporate advice and guidance on a variety of procedural, technical and special needs or topics on environmental issues as follows:

—Description or clarification of the legal or administrative procedures, tasks, responsibilities and time-table for carrying out an environmental impact assessment in accordance with the provisions of the operative statutes. An example is the advice and guidance issued by the Council of Environmental Quality (CEQ) in the United States to federal agencies on the implementation and preparation of environmental impact statements (EIS).

—Explanation and/or detailed description of the procedural activities to be followed in the preparation and submission of an environmental impact assessment to the responsible agency or authority for decision. Such guidelines may address one or more subject areas or activities such as plans, policies, highways, industrial projects or other sectoral interests.

—Explanation and/or detailed description to provide technical understanding and advice on how to carry out assessments for particular types of development activity such as power stations, dams, plans and policies, etc. A wide range of guidelines are available, notably those prepared by the World Bank and other international aid organisations.

—Explanation and description of environmental techniques and methods including the use of checklists and matrices, evaluation of impacts, presentation of documents and public participation methods. Examples include manuals prepared by the Thailand National Environment Board for the preparation of Environmental Impact Evaluations, and by the United Kingdom Department of the Environment on the Assessment of Major Development Proposals.

—Detailed descriptions of environmental factors in specific areas of concern such as health, water, air quality, population and toxic materials. Examples include publications issued by the World Health Organization and the United States Environmental Protection Agency.

Guidelines provide an important aid to the communication of a variety of information, advice and guidance on the environmental planning and management process by and between government departments, and to public and private enterprises, and members of the general public.

As environmental impact assessment is a relatively new process to a number of developing countries, experience suggests that an effective environmental control system may take many years to implement. It is during this period, that procedural and technical guidelines are of the greatest value in setting out the legal and administrative requirements of the system, and in the development and training of manpower to carry out the technical tasks.

The need for procedural guidelines is in part dependent on the legal, administrative and institutional arrangements obtaining in each country. There would be advantage, however, in introducing the concept of EIA as a management tool to cover all types of development. Procedural guidelines that would be beneficial to countries about how to develop an environmental system might cover the following:

— the purpose and need for environmental impact assessment.
—how and when to prepare an EIA in the decision-making process.
—need for co-operation within and between central and local levels of government and others.
— advice on the format and content of EIA documents.
— publicity requirements at national, regional and local levels.
— Public participation and presentation techniques.
— post-auditing and monitoring procedures.
— institutional requirements for EIA.
— glossary of environmental planning and management terms.

EIA methods and techniques are now widely applied in Europe and in North American countries, and in a number of developing countries. It is clearly important for countries wishing to modify or extend their decision-making processes to take account of environmental factors, to be aware of the implications of adopting the use of EIA methods at an early stage. Incorporation into the legal decision-making process is likely to affect a whole series of existing regulations and procedures, which may or may not be geared to this kind of innovation. The ease to which this can be done will vary from country to country.

While considerable research efforts are being devoted to technical investigations of methods and parameters to be used, it must be pointed out that this is of no legal value and it does not in itself result in protection of the environment. Experiments in methods of administration in some sectors may also be valuable, but this is out of place in the environmental field, where the seriousness of the issues faced, and the urgent need for action, demand quick and positive action.

In summary, achievements in environmental planning and management have been mixed. Considerable progress has and continues to be made in defining the scope of the problems and in developing appropriate tools to deal with them. The real problems, however, continue at the implementation level. The major areas of concern are:

— Continuing conflict between socio/economic and environmental protection and management goals.
— Institutional aspects of environmental planning and management control in relation to other development activities.
— Inadequacy of financial and human resources to meet the environmental challenge.

Environmental planning and management can be demonstrated and promoted, but the responsibility for implementation of the appropriate management, assessment and supporting measures must rest with the governments concerned.

What Models Exist

During the Sixties, management of the environment began to occupy an increasingly important place in the social construction programmes in many developed countries. Administrative and new institutional systems were introduced, in order to achieve the new aims of environmental policy, and to deal with existing and new legislation on public and private activities.

The expansion of central and local government administrations is another important aspect in the work of environmental planning and management. For example, the creation of the National Environmental Protection Board in Sweden in 1967, the Department of the Environment in the United Kingdom in 1970, and the Council for Environmental Quality (CEQ) in the United States of America which was established to administer the National Environmental Policy Act of 1970. The USA was the first country to introduce formal procedures for EIA, and to indicate in general terms when an EIS should be produced and what it should contain. The formation of the Environmental Protection Agency (EPA) as an autonomous agency (Figure 3) in 1970, to review all EIS proposals which have implications for air and water pollution, noise, solid waste disposal, pesticides and radiation was accompanied by the reinforcement of regional and local administrations. Generally, EPA has no authority to stop a project sponsored by another federal agency though it can request more information and analysis regarding an action that it feels may be environmentally hazardous, or refer the matter to the CEQ. Similar steps have been taken in other developed and developing countries to establish environmental legislation and control systems.

In general, the environmental planning and management systems have been based on administrative measures, such as legislation, physical planning control, and the adoption of project authorisation procedures under which permission is needed from public authorities before they can be undertaken. In addition to purely administrative expedients, arrangements have been made for the granting of subsidies and the charging of levies to cover, for example, the cost of collection, treatment and disposal of solid wastes, sampling, analysis, etc. Since the 'polluter pays' principle has become more generally accepted, the dividing line between administrative and financial control has become less clear.

In most developed countries, there is a strong tradition of physical planning controls which locate public and private development projects in accordance with statutory approved development plans and policies. The examination of development applications for various permissions, including concurrence with pollution emission standards and other requirements, indicate the preconditions for various activities in individual cases.

Environmental Legislation

Developments in international environmental law are comparatively new but a number of concepts and principles have become firmly established over the years from a number of sources. They have emerged from international declarations, resolutions and charters and from specific commitments and implied assumptions, common to a growing variety of international agreements. National and local (municipal) legislation, has a more or less direct impact on the process of formulating law by establishing standards of environmental health, and what is acceptable in respect of certain action in the natural and man-made environment.

Of importance to maritime nations with extensive coastlines is the prevention of pollution of coastal waters by oil spillages from passing ships. The enactment and enforcement of such legislation is clearly facilitated if maritime nations are signatories to one or another of the various international charters or conventions on the protection of oceans from pollution.

The primary aim of environmental protection legislation is to protect the environment from the emission of pollutants into water and air, noise and light disturbance, vibrations, etc., from land and installations. As a general rule, compliance with the legislation ensures that all protective measures are taken to counteract any nuisances, as well as an acceptance of the limitations that may be imposed. Legislation may also protect individuals affected by particular nuisances by providing a right to object, in order to obtain compensation for any loss that may occur.

Environmental Administration

Traditionally, government administration is characterised by a number of ministries and departments, boards and committees with national and local administrative offices spread throughout the country according to boundary jurisdictions. Major ministries are usually arranged along sectoral lines, such as defence, finance, foreign affairs, agriculture, fishing, housing and planning, public health, communications, industry, education and so forth. A ministry of home affairs or the interior, may have responsibility for local administration, police, land, public welfare, town and country planning, rural development and policy planning. There may also be a number of advisory policy units attached to the office of the head of state.

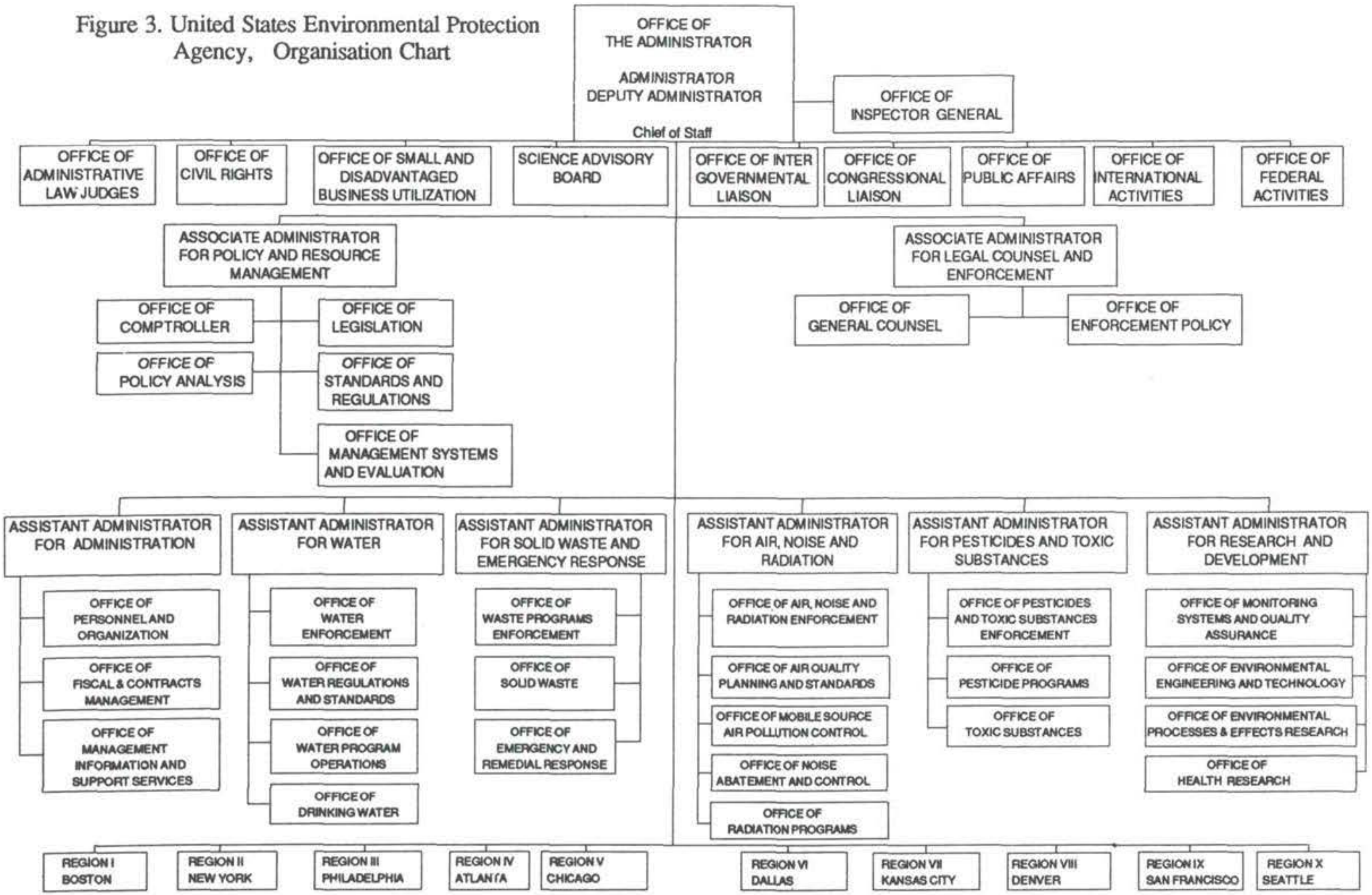
The principle tasks of ministries and their departments are to provide guidance, through appropriate legislation and financial procedures, and to deal with and resolve problems as and when they arise. Administrative boards and committees are usually responsible for exercising governmental decisions for particular areas of concern such as the environment. In this context, the responsibility for environmental questions may rest in one or more ministries, or be delegated to an executive board and supporting committees depending on the prevailing circumstances. Clearly a number of ministries are likely to be involved in environmental issues, for example, physical planning and pollution control.

In countries where difficulties arise in identifying an appropriate ministry or department to assume overall responsibility for environmental protection, Environmental Protection Boards have been formed as the central administrative authority in the environmental field. In a number of instances, the boards have been dependent upon various expert advisory committees for technial suggstions and advice on programmes for different aspects of the environment, and on procedural and institutional matters. A typical organisation chart based on the environmental administration in Thailand is shown in Figure 4.

The Thailand National Environment Board (NEB), established in 1975, has published and distributed a manual of guidelines dealing with impact evaluation procedures to all agencies and individuals in both public and private sectors. The intention of the guidelines is to initiate an appropriate system of environmental impact assessment. The manual includes guidelines for preparing Initial Environmental Examinations (IEE), for preparing Environmental Impact Statements (EIS), and for preparing terms of reference for inviting proposals from consulting firms or other agencies interested in carrying out EIS studies for particular projects. The intention is to update the manual as experience is gained in environmental planning and management.

Harmonious relationships between national environment boards and other government ministries, departments and agencies is crucial to the effective development of a national environmental planning and management system. The establishment of expert advisory groups or committees, with appropriate interests represented, can play a vital role in the development and understanding of environmental matters, and in achieving cooperation both with and between government ministries and departments. It is also important to recognise that environmental administrations within and between large urban areas represent a parallel to those of the environment as a whole. The duties and organisation of national environment boards may be reflected in the necessary adjustments that need to be made to the administration and organisation of larger urban areas.

Figure 3. United States Environmental Protection Agency, Organisation Chart



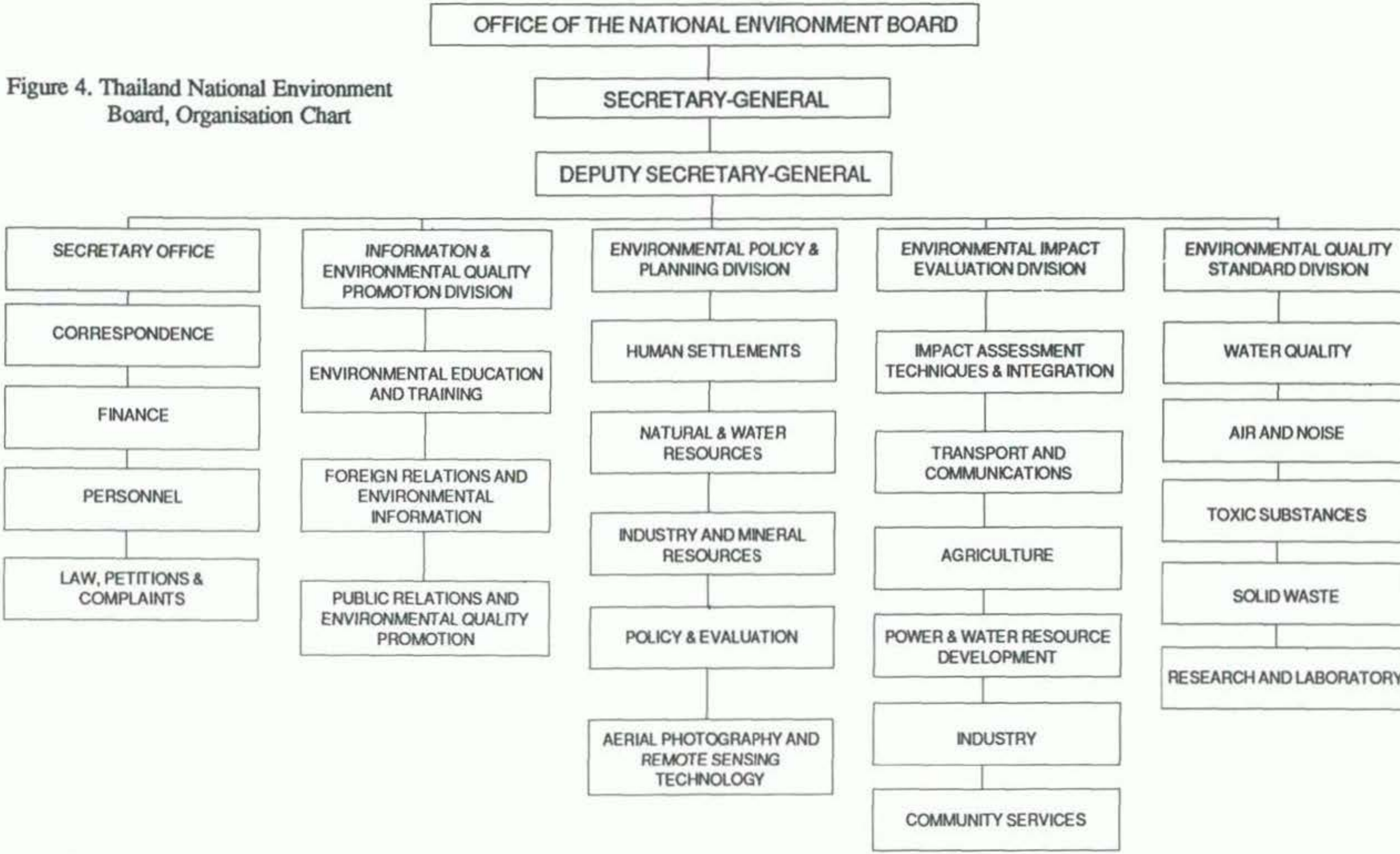


Figure 4. Thailand National Environment Board, Organisation Chart

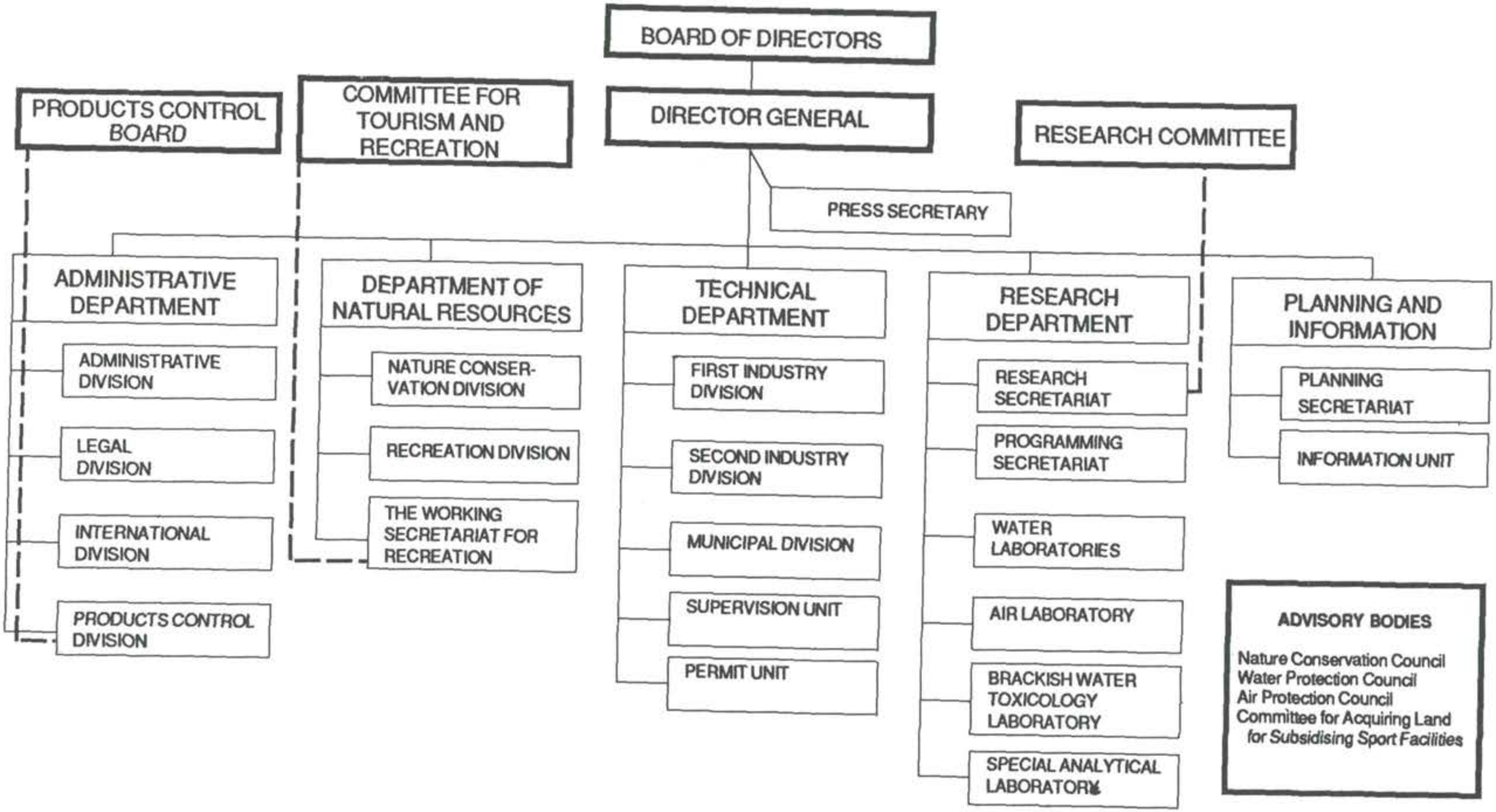


Figure 5. The Swedish National Environment Protection Board, Organisation Chart

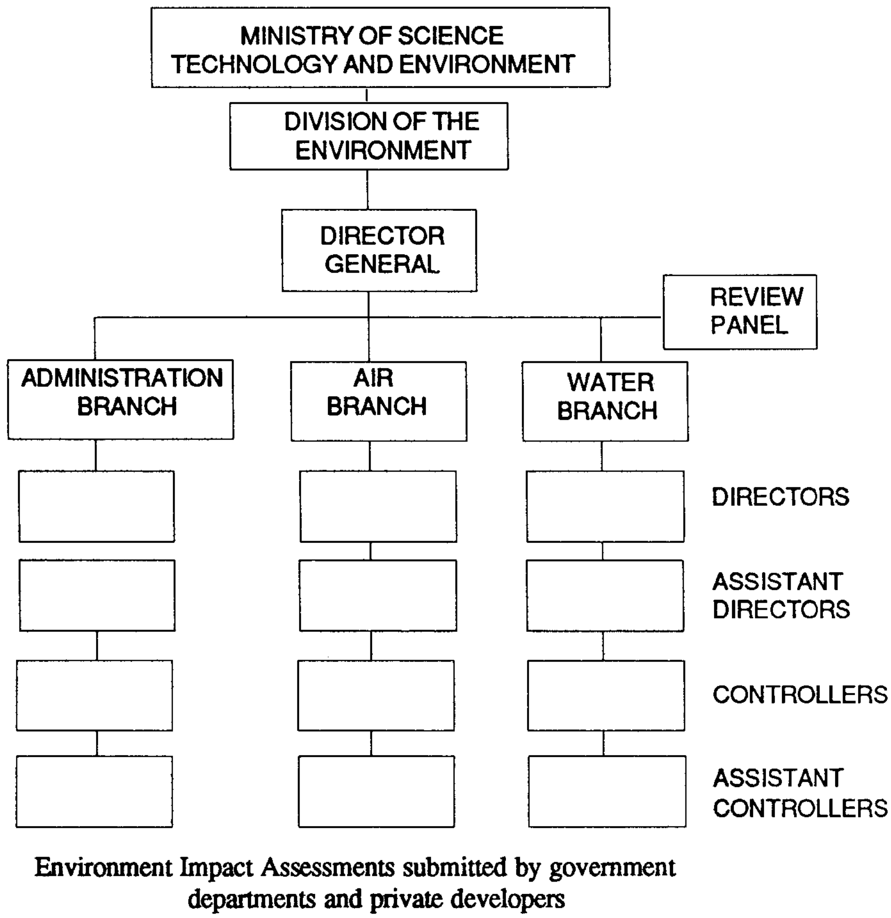


Figure 6. Malaysian Division of the Environment, Organisation Chart

Many countries with experience in town and country planning have, or are about to, assimilate EIA methods and techniques into their administrative systems of project authorisation. This is of particular importance to member states of the European Economic Community (EEC) which has now promulgated a directive on a mandatory system of environmental impact assessment for public and private projects.

According to a recent survey of the EIA process in the seventeen countries bordering on the Mediterranean, only two countries, France and Israel, have well established obligatory EIA procedures. EIA is legally required in Yugoslavia but this is of recent origin, and not yet well-established. In Turkey, the necessary procedures will be established but this still awaits background legislation. Other countries such as Spain, Syria and Libya require EIAs in certain sectors but this has not been rigourously applied. Due to the EEC directive, Greece, Italy and Spain are required to establish a mandatory EIA system by 1988.

In Sweden, the National Environment Protection Board was set up in 1967, as the central administrative authority for environment protection, and for implementing government decisions. This was accompanied by a reinforcement of local administrations with special environment-protection units. The range of responsibilities includes environment protection, water and air conservation, waste management, environmental information, active open-air life, nature protection and hunting. The Board, which is divided into five departments subdivided into divisions (Figure 5.), is subordinated to the Ministry of Agriculture which has the overall responsibility for environment protection at government level. It is led by a board of directors nominated by the government and is headed by a Director-General.

The board of directors has nine members: representatives of the Swedish Confederation of Trade Unions, the Federation of Swedish Industries, the municipalities, the popular movements and parliament. Two staff representatives are on the board of directors. A number of other ministries, boards, advisory bodies and local units are concerned with wider environmental questions, such as the Ministry of Housing which has responsibility for national physical planning, the Products Control Board which is an independent authority, but linked administratively to the National Environment Protection Board by its secretariat. The co-ordination of state efforts for tourism is entrusted to the Committee for Tourism and Recreation. The Committee's secretariat is placed at the Environment Protection Board as is the Research Committee which has both advisory and decision-making functions. The board is further assisted by three advisory bodies, namely the Nature Conservation Council, the Water Protection Council, and the Air Protection Council, and by two committees. These bodies include representatives of authorities, organisations, research institutes, etc., particularly concerned with environment protection.

In the United Kingdom, the assessment of environmental impacts has been a voluntary part of the comprehensive review process required for development proposals and actions that need authorisation from the competent local authority and other government agencies. Under the EEC directive, the UK must involve a mandatory assessment system. Over the years, various procedural and administrative arrangements for environmental protection, including the reorganisation of local government in 1975, have been introduced within the framework of the town and country planning and pollution acts. The responsible organisation in England and Wales is the Department of the Environment, and within the Scottish Office, the Scottish Development Department. The main government agencies concerned with the natural environment are the Nature Conservancy Council (NCC), which advises government on all conservancy matters, and the Countryside Commission.

In Malaysia, the Environmental Quality Act of 1974 established a Director-General and a framework to provide wide-ranging, co-ordinated pollution control and environmental protection measures. In 1975, the Malaysian Division of the Environment was established and later was incorporated within the Ministry of Science, Technology and Environment. It is organised into three departments, namely, Water Pollution Bureau, Air Pollution Bureau and Administration Bureau. The Water Pollution Bureau has two branches, the Water Quality Branch and the Industrial Effluents Branch. The former, in turn, is again composed of a River Monitoring Unit and Pollution Control Unit. (Figure 6).

Over the years Malaysia has made considerable progress in solving environmental problems related to development. For example, the third Malaysian Plan (1976-1980) included for the first time in such a development document a chapter on 'Development and the Environment' in which the national policy on the environment in general, and environmental impact assessment in particular, were set out. In 1978, the National Development Planning Committee approved an EIA procedure to provide for an administrative framework for incorporating environmental considerations into the planning and implementation of development projects. The procedure may be viewed simply as a supplementary mechanism in the existing development planning process and being especially suited for the evaluation of complex major projects.

The EIA system applies to all development works and projects initiated within the public and private sectors, and provides for a preliminary and detailed assessment followed by a review of the detailed assessment reports submitted to the project approving authority. The results of the assessments are reported formally for examination by the project approving authority. A copy is also submitted to the review panel through its secretariat in the Division of the Environment. Review of the detailed assessment reports is conducted by an independent review panel under the chairmanship of the Director-General of Environment and the head of the secretariat to the review panel. Members of the review panel are appointed personally by, and are responsible directly to, the Minister for the Environment. The membership includes:

— an ecologist or an environmental scientist
— a specialist in one of the natural resources
— a specialist in some aspect of human health
— a specialist in social or cultural affairs
— a member selected from the general public
— a member from the Economic Planning Unit of the Prime Minister's Department
— a member from the Malaysian Industrial Development Authority
— a member from the Association of Banks
— a registered engineer
— a registered architect or a registered town planner
— one temporary member drawn from the Ministry/State government agency sponsoring or responsible for the project.

The EIA unit in the Division of the Environment serves as the secretariat to the review panel. In addition, the review panel may ask suitable experts for their specialist advice on specific aspects of any project under review.

The review process is limited to a maximum period of two months during which comments are invited from concerned agencies and from the public. The review panel recommendations are forwarded to the approving authority including any conditions to be attached to the project approval. If the recommendations are that the project should not proceed, and the project proponent elects to revise or abandon the projects, the review panel's recommendations are withheld from the project approving authority and from public scrutiny.

A major drawback to the system has been the lack of an action-forcing provision. The approach of using persuasion alone as a mechanism to require developers to comply with the system is too slow and is less than satisfactory. In these circumstances, there have been many more projects across the country to which the EIA procedure should have applied. Another predicament faced by developers who are required to carry out EIA studies, is the lack of baseline information and data.

Interactions Between Agencies

The degree of inter-departmental co-operation inevitably varies with different organisational and administrative arrangements, the technical capability of staff, and the work loads which have to be met. An essential component of effective co-operation and co-ordination between various agencies is the availability and free flow of technical and other information, coupled with a clear understanding of mutual interests and concerns. This may be best achieved through the establishment of an Information and Evaluation Board to handle and process technical and other information from all sectors of government.

The early difficulties facing environmental bodies are the normal ones of any new organisation which is untried in relation to existing government bureaucracy. Again, difficulties will arise in attempting to inject environmental planning and management into traditional methods of government. It must also be appreciated that in many countries, there is still a 'low level' appreciation of environmental matters. This situation requires the active promotion of the value of the environment as a national resource in its own right, for recreation, for education, and as a habitat for wildlife.

The success or otherwise of any environmental planning and management organisation is largely dependent on the administrative skills of senior personnel in establishing a rapport with colleagues in other departments of government. Correspondingly, there must be an increase in technical competence of staff under them, and their relationship with colleagues. At the same time, continuing basic improvements must be made in:

— the development of forward action in co-ordination and planning, rather than maintaining a static day-to-day enforcement system.
— the development of extended areas of co-operation and support within the political, bureaucratic and private sectors.
— the development of an information system which should be readily available to other departmental users.
— the development of credibility through an improvement in its internal organisation and image.

Despite the considerable efforts that have been made to build-up and improve environmental planning and management systems, it is generally recognised that the system has a number of weak points. These include:

— the shortage of technical staff to deal with the many complex environmental issues that arise.
— the lack of long-term planning in major sectors of the environment.
— the lack of macro-economic frameworks in which to relate and co-ordinate investment programmes in the planning and environmental process.
— the lack of expertise to prepare feasibility studies and undertake environemntal

appraisals of special projects.
— the lack of an overall physical planning framework to control the location of development projects and to protect the environment.

Technical and Educational Support

Improvement in the quality of life largely depends on the protection and enhancement of the natural and man-made environments. This can best be achieved by giving attention to the following:

— participation in international actions to protect coastlines from the threat of oil and other pollution, and from other exploitation;
— the improvement of human settlements by the provision of essential infrastructure services;
— control of potential air, water and land pollutants by the enforcement of existing and new environmental legislation in both urban and rural areas;
— protection of agricultural and green areas from haphazard development and rubbish disposal;
— better distribution of population with opportunities to live in favourable environmental conditions; and
— the preservation of historic and archeological sites.

All of these environmental issues are inter-related and composite solutions are necessary to achieve an equitable balance between them. This can best be done by the creation of environmental policies and, as already indicated, by the establishment of an effective administration and technical framework. This, in turn, must be supported by an educational programme to progressively train the necessary staff, and inform the general public about environmental issues.

Procedural and technical guidelines are effective in imparting knowledge but they cannot provide the practical training in carrying out environmental assessments and research studies. This can best be done through seminars and training workshops which encourage questions and discussions by participants. Project simulation exercises to involve participants in each stage of the process are crucial to practical understanding and appreciation of what is involved.

The dual approach of guidelines and training workshops reflects the requirements for early training in planning and management of resources. In the short-term, guidelines will help improve the understanding and capability of all concerned, and training workshops will assist personnel to interact more meaningfully with consultants, colleagues in other departments, and eventually to undertake all the necesssary environmental tasks. In addition to the short technical courses, it is necessary to consider the need for the provision of full-time education and research facilities to train professional planners and environmental scientists.

It is recognised, again, that the ability to respond to these issues is largely dictated by the availability of financial support, trained personnel, and the adequacy or otherwise of existing organisational and co-ordination arrangements within various ministries, departments, boards, committees and local administrations. Clearly, the provision of effective management and planning is essential for future development. Therefore, there can be little doubt that environmental training programmes are required to create and maintain awareness and understanding of environmental issues amongst members of the public and government officials.

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