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PROCEEDINGS OF THE WORKSHOP ON ADOPTING, APPLYING AND OPERATING ENVIRONMENTALLY SOUND TECHNOLOGIES FOR DOMESTIC AND INDUSTRIAL WASTEWATER TREATMENT FOR THE WIDER CARIBBEAN REGION

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CARIBBEAN ENVIRONMENT PROGRAMME

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FOREWORD

The enhancement of awareness and the development of the capabilities of managers and decision makers at a regional and national level are among the program priorities of UNEP's International Environmental Technology Centre (IETC) and the Regional Coordinating Unit of the Caribbean Environment Programme (CAR/RCU). In particular, knowledge of the issues in adoption, application and operation of environmentally sound technologies (ESTs) has become essential in planning the sustainable use of natural resources and the reduction of environmental impacts from human activities like waste.

IETC has already undertaken two pilot workshops on Adopting, Applying and Operating Environmentally Sound Technologies in different parts of the world. The first one was held in September 1996 in Dresden, Germany and focussed on Urban and Freshwater Resources. The second was in December 1997 at Murdoch University in Australia and focussed on Urban Management.

The Workshop for the Wider Caribbean Region, held in Montego Bay, Jamaica, November 1998, has its origins in the Dresden Workshop, where participants from the Caribbean and the Atlantic Region elaborated proposals for regional follow-up. In the Dresden Workshop, training modules were prepared by Murdoch University encompassing presentations from specialists on industrial and domestic wastewater treatment as well as country representatives. Presentations during the workshops addressed different key issues such as information systems and databases related to ESTs, alternative technological approaches to treatment, technological solutions and innovations and the identification of future actions by the countries.

The Montego Bay Workshop gathered national experts from 20 Technical Focal Points in the Wider Caribbean Region plus a number of experts on wastewater treatment, private enterprises, members of the US Peace Corps, and representatives from various international agencies such as the US Agency for International Development, European Union, Caribbean Environmental Health Institute and German Technical Cooperation (GTZ). Also, as part of IETC's and CEP's support to the Program for Small Island Developing States (SIDS) a government official from the island of Cape Verde in the Atlantic was invited to participate and share experiences with experts from the region.

The Workshop provided experts from Governments in the Region with the basic concepts related to Adopting, Applying and Operating Environmentally Sound Technologies (ESTs). This background in ESTs was supplemented with information on the latest technological alternatives for the treatment of industrial and domestic wastewater. The IETC and UNEP-CAR/RCU believe that the Workshop has provided a sound basis for ESTs to be considered in the planning process when governments are identifying and selecting technologies to suit their specific needs.

Lilia Casanova Nelson Andrade Colmenares
Deputy Director and OIC Co-ordinator
IETC UNEP-CAR/RCU

EDITORIAL

Communities in the Wider Caribbean Region have a strong desire to improve their environment. This desire was clearly expressed in the country presentations given by delegates to the UNEP Workshop on Adopting, Applying and Operating Environmentally Sound Technologies for Domestic and Industrial Wastewater Treatment.

There was as well a general realization that the solution to environmental problems facing the marine environment in the region lies with communities themselves, and that the future will be shaped by steps and actions taken within the region. Furthermore a significant contribution can be made by the country delegates attending the workshop. It was therefore a pleasant and rewarding experience for the group from Murdoch University to facilitate the workshop to help define the existing problems more clearly, to consider technologies that have been developed within the region and elsewhere, and to assist country delegates with developing strategies that they can implement in the short, medium and long term in their countries.

The process described above began quite some time before the workshop with countries in the region identifying national experts to send as delegates to the workshop, and with the preparation of country papers by the delegates. At about the same time, specialists familiar with the environmental problems faced by developing nations came to present technologies that can provide solutions to the problems that were identified by country representatives.

From the country papers (Part 2 in this book) it becomes obvious that the existing situation in the Wider Caribbean Region is generally similar, differing only in the degree of the problems experienced. There is a lack of collection and treatment of wastewater, with much of it ending in the marine environment and impacting negatively on it. The marine environment is a major tourist attraction that needs to be protected to ensure its long term viability. Where there is collection and treatment of wastewater, the facilities are not generally operated or maintained to specification. Lack of resources, personnel, training of personnel, institutional arrangement or enforcement of legislation were mentioned as possible causes. While there is cultural and economic diversity in the Wider Caribbean it appears that the experience in the region is not very different from the experience elsewhere as illustrated by the case study of Cape Verde, an island located west of the continent of Africa.

Invited speakers presented papers (Part 1 of this book) on technologies that have been successfully used in both developed and developing countries. We think this is an important point to make because technologies that are proposed for developing countries should not be seen as being appropriate only for the latter. We are very pleased to see papers from the United States, Canada, South America and Australia giving examples where technologies have been demonstrated to be equally applicable in both, having regard to long term sustainability.

While papers were presented on specific technologies for wastewater management, these were placed in a wider context by other presentations. The other presentations covered subjects ranging from technology choice and sustainable development, the basic scientific understanding required to assist with the choice of technology, impact of waste disposal on the marine environment, to the development of a protocol to control pollution of the marine environment of the Wider Caribbean Region developed by countries in the region.

Two major benefits of workshops are the networking of delegates and the exchange of ideas that make the contribution of individual papers greater than their sum. We are pleased to report that these two were very evident during the workshop. Presenters from outside and within the region were questioned about their ideas and their applicability for the region. Sources of information were made available and a number of these were formally presented.

A significant outcome of the workshop is the deliberation of delegates on what steps they can take in the short, medium and long term to assist with efforts to protect the marine environment in the region from land based discharges of wastewater. These were formalized on the last day of the workshop through discussion groups summarising the existing conditions, current technologies and future options.

We trust that the networking achieved at the workshop and the outcome of the workshop, which includes this publication containing proceedings of the workshop, will contribute towards achieving a better marine environment in the Wider Caribbean Region. We would like to suggest that we follow up the recommendations made at the workshop after a year or two to assess where steps have been taken and improvements made, and what further steps are required to achieve the goal.

We commend the initiative of UNEP IETC and UNEP - CAR/RCU and invite readers to evaluate the papers for application in their specific community, country or region. We would also like to welcome comments and suggestions on papers presented at the workshop and on the workshop itself.

Goen HoDirector, Institute for Environmental Science
Murdoch University
Perth, Australia
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PART 1

INVITED PAPERS

Technology Choice and Sustainable Development

Dr Martin Anda
Institute for Environmental Science, Murdoch University, South Street, Murdoch WA 6150, Australia
Tel: (61-8) 9360-6123, Fax: (61-8) 9310-4997, Email: anda@essun1.murdoch.edu.au

The Concept of Sustainable Development

In recent years, the pursuit of Sustainable Development has become a goal common to environmentalists, economists, development theorists, governments, and even many industrialists. This broad-based concern for both environment and development is part of a second wave of modern environmentalism (Beder 1993, p.xi).

The first wave of modern environmentalism peaked in the 1960's and early 1970's. During these years a significant number of scientists began to express their concern for environmental issues such as the effects of pollution and the depletion of non-renewable natural resources. There was also a rapid increase in public concern for the welfare of the natural environment. Nature conservation organisations expanded their interests to include environmental issues, and new organisations and societies were formed specifically to draw attention to environmental issues (e.g. Greenpeace formed in 1971).

Environmentalism in the 1960's and early 1970's was different to environmentalism today in that it had very little support from mainstream economists and industrialists. It was also much more antagonistic towards industry, and the western capitalist ideal of pursuing never-ending economic growth. First wave environmentalists voiced concern that population growth and the growth of industry could not be sustained indefinitely. Many argued that a global ecological crisis was imminent, and the pursuit of economic and industrial development was held to be responsible (e.g. Meadows *et al*. 1972). At the time, governments were reluctant to acknowledge the presence of global environmental problems, or to recognise the possibility of a global ecological crisis. However, many governments in wealthier nations (including Australia) responded to community pressure and introduced clean air acts, clean water acts, and other forms of environmental legislation.

The first wave of modern environmentalism lost its momentum in the late 1970's and early 1980's, largely because a number of writers began to argue that a global environmental crisis was just doomsday fantasy (see Beder 1993, Adams 1990). These views were quite popular amongst some leading members of the governments of affluent industrialised nations. Governments which had previously responded to community pressure to place environmental restrictions on industry, bowed to growing pressure from both industry and the public for economic growth. Governments became less enthusiastic about getting involved in the introduction of new environmental legislation, and in some cases they became reluctant to enforce existing legislation.

The second wave of modern environmentalism began in the late 1980's. One of the events that helped this second wave along was the emergence of convincing scientific evidence about the build-up of greenhouse gases in the atmosphere, and convincing evidence that the ozone layer was being depleted. Another significant event was the release of The Brundtland Report[1] in 1987 by the United Nations World Commission on Environment and Development. In the Brundtland Report the World Commission argued that the world was in urgent need of both environmental protection *and* economic development. Thus, it proclaimed, sustainable forms of economic development needed to be encouraged. The World Commission defined Sustainable Development as:

> *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs."*

The Brundtland Report was not the first publication to suggest that development needed to be sustainable, or the first to give a definition of sustainable development.[2.] However, it was much more influential than previous documents because the timing of its release, and also because of the prominent position of its authors in the international political arena. At the time of the release of the Brundtland Report Sustainable Development was approved in the UN General Assembly and also accepted as a national goal by the governments of 100 nations (Beder 1993, p. xiii).

Critics of the Brundtland Report have argued that the Brundtland Report's definition of Sustainable Development is very loose, and that this has allowed different interest groups to interpret the definition in ways that suit their own specific goals. They argue that whilst interest groups may all agree that the environment must be protected, they often have different ideas about which bits of the environment should be protected, different ideas about how it should be protected, and different ideas about what development is. In other words, although interest groups may all agree that the pursuit of Sustainable Development is important and necessary, they often disagree about how it should be pursued.

This became very apparent in 1990 when the Australian Commonwealth Government set up a number of working groups to formulate a National Strategy for Ecologically Sustainable Development. The working groups were to study how Sustainable Development could be applied to nine industry sectors that were thought to have a significant impact on natural resources. These sectors were: agriculture; energy use; energy production; transport; mining; fisheries; forest use; tourism; manufacturing.

The working group members consisted of representatives from government, industry, unions, consumer/social welfare organisations, and conservation groups. Summaries of the working group's findings were released in 1992. Some representatives from conservation and environmental organisations were not satisfied by the way the working groups operated. They felt that intersectorial issues (the issues that crossed sector boundaries) were not dealt with

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[1] The Brundtland Report was entitled "Our Common Future" but it is commonly referred to as the *Brundtland Report* after the World Commission’s chairperson Gro Harlem Brundtland. Commonly referred to as the *Brundtland Report* after the World Commission's chairperson Gro Harlem Brundtland.

[2] Other writers and committees had given definitions for Sustainable Development years earlier eg. the UN Conference on the Human Environment held in Stockholm in 1972, and the World Conservation Strategy published in 1980.

properly. Other environmentalists argued that contentious issues and recommendations were left out in the effort to reach consensus, and that the policy options and recommendations that appeared in the final reports were conservative and aimed at slow incremental change rather than the more radical dramatic change which they felt was necessary.

Environmentalists have leveled similar criticism at the United Nations Conference on Environment and Development which was held in Rio de Janeiro in June 1992. Agenda 21, a program of environmental action for the 21st Century which the UN hopes will be undertaken by all nations, was criticised as being weak and without strong statements on important but contentious issues such as the role of trans-national corporations, population control, and consumption in affluent nations.

The Brundtland Report's version of Sustainable Development, which is the basis of the Australian Commonwealth Government's National Strategy, has also been criticised by those in the field of Development Studies. Some writers specialising in development issues have argued that the Brundtland Report is essentially just a reformed, greener version of "developmentalism"[3]. They argue that the Brundtland Report looks at the environment from the perspective of affluent industrialised nations (which they refer to as the *core*). Sustainable Development, in their opinion, *should* look at the environment from the perspective of poor Third World communities (the *periphery*). Thus, rather than primarily focusing on reducing the environmental impact of existing economic practices, affluent industrialised nations should look at changing existing economic practices in order to ensure that the poor have a secure and sustainable livelihood (Adams 1990, p.5, 198; Chambers 1987).

Zethoven (1991) defined three positions present in the Sustainable Development debate: shallow, intermediate and deep sustainable development. The first assumed that natural and human-made assets could be substituted while the other two couldn't. The Business Council of Australia and the Australian Government, for example, fitted the 'shallow' position with their continued support for indiscriminate economic growth even with the loss of "unimportant species". The ecologically sustainable development package brokered by the Australian Government between industry and the mainstream conservation organisations on this shallow basis resulted in Greenpeace walking out of these negotiations (Beder, 1994). The Brundtland Report espoused an 'intermediate' position which would accommodate growth in developing countries to achieve a *sustainable livelihood security* while growth in the industrialised world was to be curbed. Many environmentalists fit the 'deep' position of sustainable development and interestingly this is perhaps the position applicable to Fourth World communities. Within a framework of 'deep' sustainable development local communities, for example, remote indigenous communities, are able to undertake limited and finite growth to remedy the disadvantage they suffer within an industrialised nation.

Beder (1994, p39) called for a 'third wave' of environmentalism which would "transcend both the protest [first wave] and consensus [second wave] approaches of recent decades."

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[3] The term "developmentalism" is used to describe the view that all countries should progress down the (linear) path towards modernisation, and that progress the path can be measured in terms of economic growth and the rate at which modern technology is adopted.

References on Sustainable Development

Adams, W.M. (1990) Green development: Environment and sustainability in the Third World. Routledge, London pp. 14-65.

Adams, W.M. (1993) Sustainable Development & the Greening of Development Theory, in F.J. Schuurman (ed), Beyond the Impasse, Zed Books, pp. 207-222.

Beder, S. (1993) The Nature of Sustainable Development. Scribe Publications, Newham, Australia. pp. 3-8.

Beder S (1994), Revoltin' Developments: The politics of sustainable development, Arena Magazine, June/July, pp. 37-39.

Bookchin, M. (1983) An open letter to the ecological movement. RAIN, Oct/Nov.

Brundtland, H. (1987) Our common future. Oxford University Press, Oxford (for the World Commission on Environment and Development). pp. 45-65

Chambers, R. (1987) Sustainable Rural Livelihoods: A Strategy For People, Environment and Development. Overview paper for Only One Earth; Conference on Sustainable Development, IIED, London, 1987

Commonwealth of Australia (1992) National strategy for Ecologically Sustainable Development. December, AGPS, Canberra. pp. 6-19 (Introduction)

Meadows, D., Randers, J., Behrens, W.W. (1972) The Limits to Growth. Universe Books, New York.

Sachs, W. (1992) Whose environment? New Internationalist 232, 20-22.

World Commission on Environment & Development (1995), Towards Sustainable Development, in Conca *et. al.* (eds), Green Planet Blues, Westview Press, pp. 211-221.

Zethoven I (1991), *Sustainable Development - a critique of perspectives*, in Immigration, Population and Sustainable Environment, Smith J W (ed), Flinders University Press, Adelaide.

Technology for Sustainable Development

As explored in the previous section, there are a range of physical and social factors which are going to determine whether economic activities are sustainable or not. An important element in these physical and social dimensions of sustainability is the *choice of technology* and whether or not the technology is appropriate in a given set of circumstances.

The concept of *Appropriate Technology* (AT) was first synthesised by E.F. Schumacher and expounded in his landmark work Small is Beautiful. A definition of AT which accords closely with Schumacher's original ideas is that of: "*a technology tailored to fit the psychosocial and biophysical context prevailing in a particular location and period*" (Willoughby, 1990).

As with sustainable development, the subject of AT is an enormous one in itself. The term AT has been widely and loosely used to cover a multitude of concepts depending on the particular emphasis and agenda of the author. Some have referred to it in a derogatory way, calling it a "bandwagon" term covering everything from philosophical approaches to technology, ideologies, political-economic critiques, social movements, economic development strategies, particular types of technical hardware, and 'anti-technology' activities (see Willoughby, 1990, pp. 16-17). Despite these criticisms, the idea of AT remains central in the pursuit of sustainable development in affluent and less affluent countries, and is a key concept in the evolution of new environmental technologies.

The most comprehensive discussion of the philosophical issues concerning AT can be found in Willoughby (1990). What is important to recognise here is that:

- it is indeed possible to choose technologies which are inappropriate in the prevailing physical and social circumstances (many examples are provided in the essential readings), and;

- it has become crucial to give a great deal more thought to the appropriateness of technologies because:

    a. if this is not done then even the technical task to which the technology is directed will not be accomplished and
    b. particular technologies bring with them underlying structures and assumptions which may be destructive to the society in which they are introduced.

Thus, if development is to become more sustainable, it is important to assess technologies on a number of different criteria before adopting them. These criteria cover the technical, social and economic requirements of the specific situation. This applies as much to so-called 'environmental technologies', as it does to more mainstream technological approaches.

References on Technology Choice

Azelvandre, J.P., (1994) Technology Choices For A Sustainable Future: Some Conditions and Criteria For Appropriate Technology. Ecotech '94 Papers and Discussions.

McRobie G (1991), Ideas into Action - the early years, Appropriate Technology, 18, 2: 1-4, IT Publications, London.

Mitchell, R.J. (1980) Experiences in appropriate technology. The Canadian Hunger Foundation, Ottawa, Canada.

Sachs, W. (1992) Technology as a Trojan horse New Internationalist 232, 12-14

Smillie I (1991), Mastering the Machine: Poverty, aid & technology, IT Publications, London.

Willoughby, K. (1990) Technology choice: A critique of the appropriate technology movement. Westview Press, Intermediate Technologies Publications, London.

Land-Based Sources of Marine Pollution
In the Wider Caribbean Region

A Protocol for Action

Tim Kasten
Programme Officer, UNEP-CAR/RCU, 14-20 Port Royal Street, Kingston, Jamaica
Tel: (876) 922-9267, Fax: (876) 922-9292, E-mail: tjk.uneprcuja@cwjamaica.com

Background

The Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region (WCR), or the "Cartagena Convention," is the only binding regional environmental treaty for the WCR. The Cartagena Convention, presently has 20 States that are Contracting Parties out of the 28 States in the Region. The Convention is a framework convention and calls upon its Contracting Parties to develop protocols and other agreements to facilitate the Convention’s effective implementation. The Convention and its Protocols constitute a legal commitment by these countries to protect, develop and manage their common waters, individually and jointly.

Two protocols have thus far been developed. The first protocol on co-operation in combating oil spills in the WCR entered into force in 1986 with the Convention. The second protocol on Specially Protected Areas and Wildlife, adopted in 1990, is expected to enter into force in 1998. Work is ongoing on a third protocol on the prevention, reduction, and control of marine pollution from land-based sources and activities (LBS Protocol). Completion of these negotiations and adoption of this protocol is expected for the second quarter of 1999.

The LBS Protocol is a regional mechanism that will assist States in the WCR to achieve the goals and obligations of two international agreements. The United Nations Convention on the Law of the Sea calls upon Sates to adopt laws and regulations to prevent, reduce, and control, pollution of the marine environment from land-based sources.

The Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA), adopted in Washington in 1995, highlights the need for action to reduce the pollutant load to the seas from land-based sources activities. Both of these instruments emphasize the need to act at the regional level to address this problem.

Regional action is particularly important to the WCR. Because of the large number of countries in a relatively small area, almost the entire marine environment of the WCR falls under national jurisdiction. Further, the large number of countries and their close proximity and the circulation patterns in the WCR create a large number of transboundary pollution issues. This situation exemplifies the need for regional co-operation and coordination to effectively address land-based sources and activities.

Marine Pollution from Land-Based Sources and Activities in the Wider Caribbean

In 1994, the Caribbean Environment Programme (CEP) of UNEP completed an overview of land-based point sources of marine pollution in the WCR. The final report of that study (CEP Technical
Report #33), indicated that domestic wastewater was the largest point source contributor by volume to the WCR. Domestic wastewater was followed by six industrial categories: oil refineries, sugar refineries and distilleries, food processing, manufacture of beer and other drinks, pulp and paper factories and chemical manufacturing. Though not part of the 1994 study which focused on point sources, urban and agricultural nonpoint sources of pollution are also recognized as significant contributors to pollution of the WCR.

LBS Protocol Development in the WCR *--A new approach --*

Two expert meetings held in 1992 and 1994 assisted in shaping the basic conceptual and structural approach of the Protocol. Negotiations in 1996, 1997 and 1998 have brought the Protocol to the point where the Contracting Parties have agreed to hold final negotiations in the first half of 1999. The Protocol as drafted differs significantly from other regional LBS instruments and, once implemented, should result in tangible positive environmental impacts in the WCR and on the economies of the Region which are highly dependent on the marine environment.

The draft Protocol sets forward general obligations, institutional responsibilities, and procedures for acceptance and ratification in the main body of the Protocol. Specific technical annexes establish priority source categories and activities and contaminants of concern in the Convention Area; factors to be used in determining effluent limitations; and management practices, and specific obligations applicable to specific pollution sources in the region.

The first annex to the Protocol establishes a list of the sources, activities, and contaminants of specific concern for the WCR as a whole. The second annex establishes the process for developing regional source-specific controls. Future annexes will be negotiated to address these priority source categories, activities and contaminants of concern listed in Annex I and, using the factors set forth in Annex II. These future annexes will set regional effluent limitations and best management practices. Such annexes will also contain timetables for achieving the effluent limitations and management practices.

The third and fourth annexes, which are the first of the two source-specific annexes, to be adopted together with the Protocol, establish effluent limitations for domestic sewage and best management practices that are to be incorporated into national plans to control pollution from agricultural non-point sources. The effective implementation of these two annexes will commit the Parties to making significant improvements to the pollution control practices currently used in much of the WCR.

If adopted, this agreement will be the first regional seas agreement where effluent limitations and other obligations are required within a given time frame for specific sources of pollution.

Technical Assistance --*making it happen --*

In the end, the LBS Protocol is only effective if well implemented. Effective implementation of the Protocol, will require the co-operation and co-ordination of entities at the international, regional, national and local levels, the private sector, and donor institutions.

Key challenges for implementing the LBS Protocol include funding to support the identification, development, design, and construction of pollution control technologies and institutional capacity building. The Caribbean Regional Co-ordinating Unit of UNEP, as Secretariat to the Cartagena Convention, along with the Contracting Parties and other relevant organizations is designing and implementing projects to meet these challenges. Pilot projects for capacity building in various WCR countries provide models for replicability in other countries. Technology exchange takes place through workshops on appropriate technologies and best management practices. CEP has made some progress in these areas, but the need is great. On behalf of the Contracting Parties to the Cartagena Convention, the Secretariat welcomes partnerships with others to meet these needs and to prevent, reduce, and control marine pollution from land-based sources and activities.

For additional information, visit the CEP website at www.cep.unep.org/ or contact:

Mr. Tim Kasten
Programme Officer
UNEP-CAR/RCU
14-20 Port Royal Street
Kingston
JAMAICA
Tel: (876) 922-9267
Fax: (876) 922-9292
E-mail: tjk.uneprcuja@cwjamaica.com

Principles of Wastewater Treatment

Associate Professor Goen Ho
Institute for Environmental Science, Murdoch University, South Street, Murdoch WA 6150, Australia
Tel: (61-8) 9360-2167, Fax: (61-8) 9310-4997, Email: ho@central.murdoch.edu.au

Introduction

Numerous technologies are available for the treatment of wastewater. Many systems have been constructed and successfully operated ranging from simple on-site systems to sophisticated large-scale systems with computer operational control. In evaluating the technologies for application in a particular situation many factors have to be considered. These include capital cost, availability of fund, financing arrangement, cost-recovery possibility (affordability by the users), operating and maintenance, and the need for training in operation and maintenance.

There is also the wider consideration of planning to set land for the sewerage pipes, pumping stations and the treatment plant, integration of wastewater services with stormwater drainage and with solid waste disposal, community involvement and the local government and non-government processes to implement the wastewater collection and treatment project. Though these factors have to be thoroughly considered to ensure long-term viability and sustainability of a wastewater management system, an understanding of the principles of wastewater treatment is essential in enabling a proper evaluation of treatment technologies for possible application in a local situation. We need to be able to answer the question of whether a particular technology will work or indeed appropriate considering the prevailing economic, social, environmental and institutional factors mentioned above. Will a high-technology high-cost system be the answer, or will a low-cost on-site system be adequate, or will a community-scale system be the most appropriate given the set of local factors? Understanding how these technologies work will go along way towards answering the question. The understanding will also enable us to assess the adequacy of existing local technology (one that has been in used locally over many years), how to improve the existing technology, or how to adapt one of the available technologies to better fit the local condition.

The purpose of this paper is to develop principles for understanding wastewater treatment by first of all examining the natural processes taking place in nature that help to purify wastes. These principles are then applied to the examination of simple wastewater treatment systems that closely mimic nature. The natural physical, biological and chemical processes are then related to engineered systems which are more complex and where separate units may be constructed to carry out the processes. In this paper emphasis is placed on small-scale on-site engineered systems.

Natural 'Self Purification' Processes

That nature has processes that purify wastes can be deduced by examining what takes place in pristine forest ecosystem. Water quality of a stream within the ecosystem can be regarded to be very good. This situation exists even though animal wastes, leaf litter, decaying plants and animals are constantly produced within the ecosystem. These are decomposed by bacteria releasing the elements C, N, P and others to be taken up again by plants and cycled within the ecosystem. Rainwater passing through the ecosystem producing run-off which flows to the stream hardly picks up any of these.

The natural processes taking place within an ecosystem can be generalised into physical, chemical and biological processes (Table 1).

Table 1. Natural Physical, Chemical and Biological Processes Purifying Wastes

Principles	**Processes**
Physical	Settling - removal of solids from water Filtration - removal of solids as water flows through soil Aeration - oxygenate water Adsorption - removal of substances by adsorption to soil minerals or to humus
Biological	Bacterial decomposition - removal of organic substances There are numerous types of bacteria carrying out specific functions, such as breaking down carbohydrates, proteins, lipids, converting ammonia into nitrate, converting nitrate to nitrogen gas Bacterial competition controlling the population of pathogens
Chemical	Precipitation – removing substances from water percolating through soil minerals/humus

Land Application of Wastewater

Application onto land is a simple low cost system for treatment of sewage. Vegetation is usually part of the land system, and it can be harvested or grazed. The natural physical, chemical and biological processes described above remove the organic substances (usually measured by BOD), solids (SS) and soluble materials from the wastewater. The resulting water percolating to groundwater or overflowing to a stream can be of considered to have minimal environmental impact provided that the loading of the wastewater per unit area of land does not exceed the natural self purification capacity of the system. When the capacity of the system is exceeded there will be organic substances, nutrients (nitrogen and phosphorus), pathogens and others remaining unregarded and thus considered to be polluting.

Lagooning of Wastewater

Lagooning of wastewater also treats it. What takes place resembles more what happens in a lake ecosystem than in a forest ecosystem. In a lagoon system solids settle to the bottom and are decomposed by benthic organisms. Within the water column bacterial decomposition takes place. Bacteria and algae function symbiotically with the bacteria releasing carbondioxide and algae taking up the carbondioxide during the day and producing oxygen from photosynthetic activity. The oxygen in turn is taken up by the bacteria for respiration. Nutrients are removed from the water when the algae are harvested (e.g. by fish).

Engineered Systems

The primary objective of engineered wastewater treatment and disposal is the protection of public health. Wastewater of domestic origin contains pathogens, suspended solids (SS), substances causing biochemical oxygen demand (BOD), nutrients (nitrogen (N) and phosphorus (P)) and a hosts of other possible pollutants, which may need to be removed before the wastewater can be safely disposed. Standards have been developed for the safe disposal of the wastewater, and so have the technologies to meet them. The technologies that have been developed are generally for centralised large scale systems associated with reticulated sewerage, and the treated wastewater is for disposal rather than reuse. Options for reuse are recognised as being limited with large scale systems in urban areas, because of the need of a reticulation system for the treated wastewater.

On-site treatment of wastewater for individual houses is a necessity in areas without reticulated sewerage, but interest in on-site treatment is growing. One reason is that the technology for on-site treatment is maturing, and reuse of the treated wastewater is an option. Thus the owner of an on-site system has total control of the wastewater and its use. In an urban community where there is a desire to develop an urban village the treatment of wastewater from a group of houses within the urban village community offers the opportunity to achieve what is desired by such communities, i.e. integrated management of water.

The maturing of the technology for on-site wastewater treatment is due to a large part to the application of scientific principles to the improvement of the outdated septic tank technology. This paper therefore broadly reviews the scientific principles applicable to on-site wastewater treatment and reuse, and assesses available technologies with respect to their science content.

On-site treatment of wastewater may not provide all the answers to the problems of wastewater disposal and reuse. Issues needing to be addressed are, for example, whether individual householders can be expected to maintain a sophisticated wastewater treatment unit in the backyard, and the imbalance between water supply and demand in different seasons

The physical, chemical and biological bases for the treatment of wastewater to remove BOD, SS, N, P and pathogens are well established. They have been studied as part of efforts to improve the technologies for large scale wastewater treatment systems. These are shown in Table 2. They should obviously be applicable to small scale and on-site treatment systems.

Table 2. Physical, Chemical and Biological Principles Relied for Engineered Systems

Principles	Processes
Physical	Screening Sedimentation Sand Filtration Aeration Adsorption (Activated Carbon) Membrane filtration
Biological	Removal of BOD: Use of aerobic bacteria Use of anaerobic bacteria Removal of N: Nitrification Denitrification Removal of P: Luxury uptake
Chemical	Coagulation & flocculation Precipitation Chlorination

An example of an application to large scale systems is the conventional primary and secondary treatment utilising an activated sludge plant. Here raw wastewater is screened to remove large objects, then grits are removed in an aerated sedimentation tank, followed by sedimentation of the smaller suspended solids, producing a primary effluent. Further treatment by aerated microorganisms removes BOD, and sedimentation clarifies the secondary effluent, returning the microorganisms (activated sludge) to the aeration tank. Secondary effluent containing less than 20 mg/L BOD and 30 mg/L SS can be achieved without difficulty. The 20 mg/L BOD and 30 mg/L SS standard was, in fact, based on what could be achieved by primary and secondary treatment of sewage. Disposal to rivers or reuse for irrigation of recreational parks is generally permitted after chlorination to reduce the concentration of pathogens.

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Principles of Wastewater Treatment

Associate Professor Goen Ho
Institute for Environmental Science, Murdoch University, South Street, Murdoch WA 6150, Australia
Tel: (61-8) 9360-2167, Fax: (61-8) 9310-4997, Email: ho@central.murdoch.edu.au

Introduction

Numerous technologies are available for the treatment of wastewater. Many systems have been constructed and successfully operated ranging from simple on-site systems to sophisticated large-scale systems with computer operational control. In evaluating the technologies for application in a particular situation many factors have to be considered. These include capital cost, availability of fund, financing arrangement, cost-recovery possibility (affordability by the users), operating and maintenance, and the need for training in operation and maintenance.

There is also the wider consideration of planning to set land for the sewerage pipes, pumping stations and the treatment plant, integration of wastewater services with stormwater drainage and with solid waste disposal, community involvement and the local government and non-government processes to implement the wastewater collection and treatment project. Though these factors have to be thoroughly considered to ensure long-term viability and sustainability of a wastewater management system, an understanding of the principles of wastewater treatment is essential in enabling a proper evaluation of treatment technologies for possible application in a local situation. We need to be able to answer the question of whether a particular technology will work or indeed appropriate considering the prevailing economic, social, environmental and institutional factors mentioned above. Will a high-technology high-cost system be the answer, or will a low-cost on-site system be adequate, or will a community-scale system be the most appropriate given the set of local factors? Understanding how these technologies work will go along way towards answering the question. The understanding will also enable us to assess the adequacy of existing local technology (one that has been in used locally over many years), how to improve the existing technology, or how to adapt one of the available technologies to better fit the local condition.

The purpose of this paper is to develop principles for understanding wastewater treatment by first of all examining the natural processes taking place in nature that help to purify wastes. These principles are then applied to the examination of simple wastewater treatment systems that closely mimic nature. The natural physical, biological and chemical processes are then related to engineered systems which are more complex and where separate units may be constructed to carry out the processes. In this paper emphasis is placed on small-scale on-site engineered systems.

Natural 'Self Purification' Processes

That nature has processes that purify wastes can be deduced by examining what takes place in pristine forest ecosystem. Water quality of a stream within the ecosystem can be regarded to be very good. This situation exists even though animal wastes, leaf litter, decaying plants and animals are constantly produced within the ecosystem. These are decomposed by bacteria releasing the elements C, N, P and others to be taken up again by plants and cycled within the ecosystem. Rainwater passing through the ecosystem producing run-off which flows to the stream hardly picks up any of these.

The natural processes taking place within an ecosystem can be generalised into physical, chemical and biological processes (Table 1).

Table 1. Natural Physical, Chemical and Biological Processes Purifying Wastes

Principles	**Processes**
Physical	Settling - removal of solids from water Filtration - removal of solids as water flows through soil Aeration - oxygenate water Adsorption - removal of substances by adsorption to soil minerals or to humus
Biological	Bacterial decomposition - removal of organic substances There are numerous types of bacteria carrying out specific functions, such as breaking down carbohydrates, proteins, lipids, converting ammonia into nitrate, converting nitrate to nitrogen gas Bacterial competition controlling the population of pathogens
Chemical	Precipitation – removing substances from water percolating through soil minerals/humus

Land Application of Wastewater

Application onto land is a simple low cost system for treatment of sewage. Vegetation is usually part of the land system, and it can be harvested or grazed. The natural physical, chemical and biological processes described above remove the organic substances (usually measured by BOD), solids (SS) and soluble materials from the wastewater. The resulting water percolating to groundwater or overflowing to a stream can be of considered to have minimal environmental impact provided that the loading of the wastewater per unit area of land does not exceed the natural self purification capacity of the system. When the capacity of the system is exceeded there will be organic substances, nutrients (nitrogen and phosphorus), pathogens and others remaining unregarded and thus considered to be polluting.

Lagooning of Wastewater

Lagooning of wastewater also treats it. What takes place resembles more what happens in a lake ecosystem than in a forest ecosystem. In a lagoon system solids settle to the bottom and are decomposed by benthic organisms. Within the water column bacterial decomposition takes place. Bacteria and algae function symbiotically with the bacteria releasing carbondioxide and algae taking up the carbondioxide during the day and producing oxygen from photosynthetic activity. The oxygen in turn is taken up by the bacteria for respiration. Nutrients are removed from the water when the algae are harvested (e.g. by fish).

Engineered Systems

The primary objective of engineered wastewater treatment and disposal is the protection of public health. Wastewater of domestic origin contains pathogens, suspended solids (SS), substances causing biochemical oxygen demand (BOD), nutrients (nitrogen (N) and phosphorus (P)) and a hosts of other possible pollutants, which may need to be removed before the wastewater can be safely disposed. Standards have been developed for the safe disposal of the wastewater, and so have the technologies to meet them. The technologies that have been developed are generally for centralised large scale systems associated with reticulated sewerage, and the treated wastewater is for disposal rather than reuse. Options for reuse are recognised as being limited with large scale systems in urban areas, because of the need of a reticulation system for the treated wastewater.

On-site treatment of wastewater for individual houses is a necessity in areas without reticulated sewerage, but interest in on-site treatment is growing. One reason is that the technology for on-site treatment is maturing, and reuse of the treated wastewater is an option. Thus the owner of an on-site system has total control of the wastewater and its use. In an urban community where there is a desire to develop an urban village the treatment of wastewater from a group of houses within the urban village community offers the opportunity to achieve what is desired by such communities, i.e. integrated management of water.

The maturing of the technology for on-site wastewater treatment is due to a large part to the application of scientific principles to the improvement of the outdated septic tank technology. This paper therefore broadly reviews the scientific principles applicable to on-site wastewater treatment and reuse, and assesses available technologies with respect to their science content.

On-site treatment of wastewater may not provide all the answers to the problems of wastewater disposal and reuse. Issues needing to be addressed are, for example, whether individual householders can be expected to maintain a sophisticated wastewater treatment unit in the backyard, and the imbalance between water supply and demand in different seasons

The physical, chemical and biological bases for the treatment of wastewater to remove BOD, SS, N, P and pathogens are well established. They have been studied as part of efforts to improve the technologies for large scale wastewater treatment systems. These are shown in Table 2. They should obviously be applicable to small scale and on-site treatment systems.

Table 2. Physical, Chemical and Biological Principles Relied for Engineered Systems

Principles	Processes
Physical	Screening Sedimentation Sand Filtration Aeration Adsorption (Activated Carbon) Membrane filtration
Biological	Removal of BOD: Use of aerobic bacteria Use of anaerobic bacteria Removal of N: Nitrification Denitrification Removal of P: Luxury uptake
Chemical	Coagulation & flocculation Precipitation Chlorination

An example of an application to large scale systems is the conventional primary and secondary treatment utilising an activated sludge plant. Here raw wastewater is screened to remove large objects, then grits are removed in an aerated sedimentation tank, followed by sedimentation of the smaller suspended solids, producing a primary effluent. Further treatment by aerated microorganisms removes BOD, and sedimentation clarifies the secondary effluent, returning the microorganisms (activated sludge) to the aeration tank. Secondary effluent containing less than 20 mg/L BOD and 30 mg/L SS can be achieved without difficulty. The 20 mg/L BOD and 30 mg/L SS standard was, in fact, based on what could be achieved by primary and secondary treatment of sewage. Disposal to rivers or reuse for irrigation of recreational parks is generally permitted after chlorination to reduce the concentration of pathogens.

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Wastewater Collection and Treatment Systems for Large Communities in the Wider Caribbean:

Wastewater Collection and Treatment Systems for Large Communities in Venezuela

Mark Lansdell
Mark Lansdell Asociados, Parque Central, Edif. Catuche, 12-L – Apdo. 17156, Caracas, Venezuela
Tel: (582) 571-4869, Fax: (582) 574-2718, Email: Lansdell@telcet.net.ve

Abstract

A brief history of sewage treatment is presented along with experience of treatment systems in less developed countries for communities of over 500,000 people.

Some of the sewage treatment systems in Venezuela are presented and the technical and institutional problems which occurred during construction and operation are described and some of the solutions are presented. It was found that the most simple systems were the most effective and that it was important to develop solutions appropriate to local needs and avoid the technological dependence on imported spare parts.

Keywords

Low Cost Treatment; Oxidation Ponds; Plug Flow Constant Level SBR; MSBR

Introduction

At present 50% of the world's population resides in urban centres of over 500.000 and some 20% in the world's megacities of over 5 million. The world has embraced the water closet and the water carriage system for the transport and dilution of its wastes in the urban environment. The volumes of wastewater produced have overcome the assimilative capacity of lakes, rivers and the oceans. The large population centres accentuate the problem and in very few cases has an environmentally sustainable solution been found.

There are a number of large communities in the wider Caribbean still in need of a sustainable solution to their wastewater management problem. What follows is a brief history of worldwide experience of wastewater treatment and resource conservation and a description of the author's efforts in Venezuela.

History

In the east, both human and animal waste has for millennia been regarded as a resource to be recycled to the land to maintain its fertility and for the fertilising of fish ponds. Indeed Chinese fish ponds constitute the earliest form of stabilization ponds for treating night soil collected from household vaults (Baozhen 1987). The largest example of a lagoon - fish pond system is that which serves the sewers of Calcutta, India, which covers some 5000 Has. and produces 20 tons of fish per day for human consumption, some 20% of the city's total fish demand (Strauss 1990) .

In the west, human waste has received very little recognition as a resource and most early references refer to "sewage disposal" despite some failed attempts to make money out of the fertilizer value. In Britain, where the water closet was first introduced, the connection of house drains to street sewers was made legal after 1830. This caused the pollution of rivers, many cholera deaths, and injunctions against several large towns in the 1850's. This crisis motivated the first investigations of sewage purification by land treatment on "Sewage Farms". From these investigations rules were derived for determining the area of land required for a given sewage flow according to the type of soil. For example, the area of land required for the treatment of sewage by "broad irrigation" over clay soil amounted to nearly 20% of the urban area served. The Werribee facility serving Melbourne, Australia, since 1895 is the largest surviving example of a municipal broad irrigation system.

The high cost of land brought the need to intensify treatment in a smaller area and research in the 1870's brought the first trickling filter as a development of soil filtration with ever larger grain size. This so called "filter", really an attached growth reactor, was adopted widely in Britain and overseas. One of the largest systems being the Minworth plant serving the city of Birmingham, recently decommissioned after 100 years service. The rotating biological contactor is a descendant of this system. Instead of trickling the sewage over the media, the media is attached to rotating discs which alternatively immerse and expose the media to the air.

The Septic Tank has been used on quite a large scale in its more developed form as the two compartment "Hydrolytic" or "Imhoff Tank" for the removal and digestion of solids in the primary treatment stage. The largest example still in service since 1935 is at the Stickney Plant serving Greater Chicago and still handles half the flow of this, the largest treatment plant in the world. This was also the system used at Cairo in 1914 in conjunction with trickling filters.

The pressure forever more space efficient systems brought the invention of the suspended growth reactor or "Activated Sludge" system in Manchester in 1914. This system, although far more energy intensive than previous technology, was adopted rapidly and several large plants had been built worldwide by 1930 including Milwaukee, New Delhi, and New York City.

The activated sludge system has seen many variations over the last 85 years, in the author's opinion, the most significant were the modifications allowing the biochemical removal of nutrients. Once again this was a technical advance borne of a necessity. In southern Africa, water is very scarce and needs to be reused several times. In the cities of Harare and Johannesburg some 40% of the sewage flow is returned for public water supply. The urban population explosion has caused impoundments to become increasingly eutrophic, the algae making conventional water treatment systems for potable use difficult to manage. In order to reduce nutrient loads, the Republic of South Africa became the first country to introduce phosphorus and nitrogen limits of 1 and 10 mg/l on municipal effluents.

More recent developments in the 1980's have included submerged and fluidised beds which combine fixed and suspended growth in order further to reduce the area occupied by the treatment system but these systems remain very energy intensive.

Technological Relevance in a Developing World Context

The historical outline above describes the technological evolution which took place when Europe and North America where developing countries. As we have seen, the resource conservation aspect has been lost and the solutions have become increasingly costly in environmental goods. Large amounts of energy are required to operate activated sludge plants, dry and incinerate sludge, and to make and transport artificial fertilizers to farmland to replenish the nutrients we send down the sewers to enrich our lakes and oceans. This arrangement will not pass a sustainability test.

The Calcutta example on the other hand appears entirely sustainable, relying only on energy from the sun and achieving the recycle of resources and conserving nutrients. These solutions appear to be only possible where there is sufficient space. But sewage can almost always be transported to an available space. Mexico city's sewage is transported up to 50 km in tunnels and by 200 km of canals before being used, albeit in crude form, for irrigation on 60.000 Has of land (Strauss, 1990) as is the sewage of Santiago, Chile.

The use of sewage in crude form for irrigation or fish farming in the developing world however brings a need for barriers to the propagation of endemic diseases such typhoid, cholera and parasitic organisms such as intestinal nematodes and the pathogenic protozoa such as amoeba and giardia.

These organisms can be effectively removed in a series of oxidation ponds as detailed in the publications of the World Bank (Technical Paper N_s 7 & 51) and WHO (Technical report series N_ 778). The important point being that for resource recovery and drought situations where sewage must be used for irrigation, traditional parameters such as BOD become irrelevant and public health aspects such as the presence or absence of parasite eggs and numbers of faecal coli become the major concern.

Water Reuse

Where water resources are limited and the effluent must be discharged to a river system with urban water supply impoundments downstream, as occurs in southern Africa, the options become more limited due to the need to reduce the nutrient load in order to avoid eutrophication.

The significance of Phosphorus (P) can be put in perspective if we remember that I kg of P can give rise to 111 kg of biomass which on death will exert a COD of 138 kg supposing that the composition of algae is:

$$C_{106} H_{263} O_{110} N_{16} P$$

Environmental Management solutions such as detergent production and watershed management can help but will not prevent eutrophication episodes especially in the tropics where temperatures are high and the days usually sunny.

Where the urban populations are large, wetlands are not a practical option due to the need to harvest the biological growth and avoid internal P recycle. In these cases more sophisticated sewage treatment processes are needed and drinking water treatment technology adapted to the presence of algae in the raw water.

These processes include the activated sludge process modified for removal of nitrogen and phosphorous down to 1mg/l _P and 10 mg/l _N. In some cases this may be followed tertiary treatment consisting of coagulant addition and sand filtration for the removal of P down to around 0,15 mg/l.

Sewage Treatment in Venezuela

The author was posted to Venezuela in 1973 with a British consulting firm to study the clean up of the river supplying Caracas's water supply. Since 1978 his own firm has been involved with the design construction and operation of over 30 different treatment systems ranging from 2000 to 4.000.000 population.

The dilemma to be faced was which technology to use when lagoons were not a choice. This arose in the first plants which were designed on the Island of Margarita.

Where treatment systems are required to produce a low solids effluent for urban reuse and plant location requires low odour risk, variations of the activated sludge system have been used. These variants have been designed with local limitations in mind using unit processes which have not been used in developed countries since the early years of this century but which still have a place in situations where unskilled manpower is plentiful and foreign currency is in short supply.

Porlamar - Pampatar, Margarita Island

The Island of Margarita is the principal Venezuelan coastal tourist attraction and has been a free port since 1972 with regular international tourism starting in 1985. Its beaches are the best of the Venezuelan coast but increases in sewage flow overloaded the original sea outfall systems and beach coliforms exceeded 200 faecal coliforms/100ml for the first time in 1980 with rapid deterioration thereafter.

The wastewater master plan for the principal urban area, Porlamar - Pampatar, was prepared in 1975 and foresaw urban and rural reuse of the effluent and biosolids for irrigation and improvement of the arid sandy soils. Drinking water is brought to the island through a very costly 30 km pipeline and there is little to spare for other purposes.

The sewage from the Porlamar metropolitan area is pumped to a single treatment plant "Dos Cerritos" located some 3 km inland. This plant was put into service in 1989 the first stage of which has a capacity of 200.000 PE and 600 l/s average flow.

The sewage arrives via a 1000 prestressed concrete pipeline at the inlet works where gross solids and rags are removed in a 12m wide hand raked screen with a 3.5 cm clear opening. This screen is cleaned in about 30 mins. by one labourer once per day. The flow is then divided between three constant 0.35m/s velocity grit channels 20m. long. The grit is removed hydraulically, one of the three channels being cleaned every two weeks.

The flow then proceeds to an extended aeration tank with partitions to split the 17300m3 volume up into 5 cells in series. Along the long axis of the tank there is a concrete bridge from which are suspended 11 high speed (1200 RPM) surface aerators of 75 HP each.

The mixed liquor from this tank is divided amongst six settling tanks each 20,0 X 20,0 square with four inverted pyramidal pockets with a 7.0m depth of water. Sludge from each pocket is withdrawn continuously through 250 pipes and telescopic valves into a return sludge collector and lifted by screw pumps into the inlet end of the inlet works.

The clarified effluent is decanted through a perforated 750 pipe around four sides of each settling tank and discharged over a measuring weir into a series of two maturation ponds of five days design total retention time. Each pond is divided by walls into five cells in series. Effluent from the final cell not used in irrigation overflows and discharges through a 3.5 km. pipeline to the sea shore.

Hydraulic control of sludge age is obtained by withdrawing mixed liquor from the aeration tank through a constant head orifice to the sludge lagoons. The size of orifice varies with the sludge age selected there being orifice plates for sludge ages 5, 10, 15, 20, 25 and 30 days along with a blank one. The plate to be inserted varies with the anticipated loading which depends on the tourist flows. Off season resident connected population is around 80.000 and during the peak season July - August this rises to 130.000 based on the observed flow and strength of the sewage calculated at 50gBOD/PE/day.

Operating results during 1997 (arithmetic means) were as follows:

	Crude	**ASE**	**MPE**
Av. Flow	400 l/s		
N_ of samples	51	51	51
BOD	211	11.0	10.3 mg/l
SS	117.6	7.8	7.5 mg/l
F. Coli.	$10^7 – 10^8$	900.000	20 orgs/100ml

(ASE = Activated sludge effluent; MPE = maturation pond effluent)

Imported equipment at this plant included: cast iron gates (US), aerators (US) and screw pumps (FRG) and accounted for about 10% of the $ 4 million cost excluding land. Each aerator is provided with a mechanical timer which has allowed the aeration intensity to be graduated to the load with an efficiency of around 0,65 Kg BOD removed per KWh.

Problems which have arisen at the plant include:

- Power Cuts: The power supply to the island is subject to an average of three cuts per week of 30 mins. but some have lasted over 12 hours with no adverse affect on the final effluent.

- Sludge Lagoons: Due to leakage of division dykes, the sludge has not dried out in the drying lagoons which will shortly be reconstructed at a higher level.

- Salt Water Infiltration: Insufficient care was taken during the laying of the main 1500 sewer below sea level in the town with the result that some 5 l/s of brackish water is infiltrating into the sewer system raising the conductivity from 600µS to 2000µS rendering the water too salty for certain crops.

- Filamentous Algae: The first four cells of maturation ponds have experienced heavy growth of filamentous algae which makes them unsightly but does not alter their disinfection efficiency.

Within 30 days of the diversion of sewage to the new plant, coliform levels of coastal waters, previously above 20.000 had dropped to below 50/100 ml.

Juangriego, Margarita Island

The bay of Juangriego is one of the most picturesque on the island and is well known for its sunsets. The town has had a sewer system and an 800m long / 350 mm sea outfall since 1970.

With increasing development this arrangement became overloaded and bathing from beaches in the bay was prohibited in 1982.

To restore beach water quality and allow sewer extensions in the area, a treatment plant was completed in 1990 for a first stage population of 50.000 PE 150 l/s average flow.

The plant consists of an inlet works followed by a concrete lined reactor basin. This basin has been designed as a three channel plug flow constant level SBR (MSBR). The basin is divided into three channels longitudinally with three 40 HP floating aerators in each channel. At each end of the central channel, hanging flap valves induce an "S" shaped flow pattern. Sewage is introduced via pneumatically operated gates into one of the outer sections while clear effluent is withdrawn from the opposite side of the basin where the aerators are turned off allowing sedimentation. In this way the functions of aeration and sedimentation are undertaken in the same basin obviating the need for expensive clarifiers and sludge return pumps.

Operating results of the plant during 1994 where as follows:

	Crude	**MSBR Effect**	**Final Effect**
Av. Flow	25.9 l/s		
N_ of samples	50		
BOD	217.7	14.7	8.7 mg/l
SS	130.4	6.4	4.4 mg/l
F. Coli.	3.200.000		25 orgs/100ml

(ASE = Activated sludge effluent; MPE = maturation pond effluent)

The timing of the inlet and outlet gates and the aerator motor starters is controlled by a simple cam timer with an eight hour cycle. The imported material for this plant consisted only of the aerators as the gates and MCC were made locally. The cost of the plant excluding land was $900.000.

Problems which have presented themselves include:

- <u>Bacterial Foam</u>: An unidentified foam appeared after about 18 months of operation and gradually built up to a depth of 25 cm before a solution was found. Chlorinating, liming, skimming and jetting where all tried to no avail. Finally the scum boards on the effluent weirs where removed and placed around the inlet to the maturation pond. The area covered by foam in the aeration tanks is now rarely more than 10m2 and that behind the scum board never passes 1m2.

- Sponge: A type of sponge grew inside the 600m final effluent pipeline completely blocking it. A routine has been established in which the lagoon outlet is closed with a flash board once per month, a head builds up and when released flushes out any sponge buildup.

- Ecological Balance: The new lagoon created by the scheme caused an invasion of insects which in turn caused a plague of small white spiders on the trees to leeward. These where then eaten by birds and fish ate the larvae of the insects. This took about two years to reach equilibrium during which time the treatment plant was blamed.

- Filamentous Algae: The first three cells of the maturation ponds have a heavy growth of filamentous algae which as at Dos Cerritos makes them unsightly but does not effect efficiency.

Lake Valencia Scheme

Lake Valencia is one of largest freshwater bodies in South America with 350 km^2 of surface area, a volume of 7500 million m^3 with a present water level of + 408m. above sea level. Two major population centres (> 800.000 each) are located in the catchment along with 30% of national industry. Around the year 1750 the lake level fell below its natural overflow of level + 427m due to tree cutting and river diversion for irrigation of the sugar plantations which were established around the perimeter. In 1978 the lake level reached its lowest point + 401,50m and has since risen to + 407,9m, due to transfer of water from other catchments.

The discharge of sewage, industrial wastes and agricultural runoff along with 200 years of evaporation have left the lake hypertrophic with a conductivity of 2000µS; sulphates 550 mg/l; P 0,5mg/l and _N 2 mg/l. National policy is to improve the lake quality for tourism, water supply and fish culture.

The Inter American Development Bank approved a US$ 125 million scheme with the following objectives:

- Treatment of domestic and industrial wastes
- Control of Lake level
- Reuse of effluent in irrigation
- Closure of wells to aid aquifer recovery
- Aquifer recharge and desalination for future urban use
- Indirect urban reuse
- Reduction of artificial fertilizer requirements

The approved scheme calls for the construction of 90 km of interceptor sewers, 17 km force main and three treatment plants:

Name of WWTP	La Mariposa	Los Guayos	Taiguaguay
• Capacity (PE)	800.000	1.000.000	2.000.000
• Design Av. flow	2400 l/s	2400l/s	5.000 l/s
• Type	AS Tertiary	Lagoons	Lagoons
• Area Served	Central & West Valencia	East Valencia Guacara	Cagua Turmero Maracay

(PE = person equivalent at 50g BOD/day)

The two larger plants are lagoon systems with anaerobic units at the head end which include recirculation of facultative effluent for control of odours and stabilization of the pH. In both cases the effluent is to be used for irrigation in order to reduce the use of wells which have severely depleted the aquifer causing intrusion of salty water from the lake.

The Taiguaiguay system is a classic example of carrying the sewage to a remote lagoon and irrigation site rather than employing a local sophisticated plant. The sewage from Maracay will be pumped by natural gas driven pumps through 17 km of 72" force main to the Taiguaiguay lagoon system which located adjacent to an existing 90 million m^3 dam and 6000 ha. irrigation system. The idea being that effluent will not return to the lake but recharge depleted aquifers thus reducing the lake's tendency to rise.

To control lake levels, the Mariposa WWTP effluent will be discharged outside the catchment to the river Pao system which is impounded and transferred back to the Valencia city water supply thus creating a closed circuit indirect reuse system. The plant therefore must produce a very good effluent low in nutrients.

The impoundment already has eutrophication problems with dry season blooms of blue green algae *Anabaena* and *Microcystis* which cause severe taste and odour problems in the supplied water. Plans are under way to modify the drinking water treatment processes to handle eutrophic water. This is in recognition of the fact that even after point nutrient point source control has been implemented, catchment management in the developing world is difficult. Eutrophication becomes a fact of life in high intervention catchments and one must adapt and learn to live with it.

The Mariposa plant employs the MSBR variant of the activated sludge system (Juangriego type) designed to remove N and P. The secondary effluent is then dosed with alum and given tertiary filtration through a 1m bed of 3 mm sand in order to remove solids, intestinal nematodes and P.

The construction phase of the scheme is 80% complete and the WWTP's should all come on line during the latter half of 1998.

Discussion

In Venezuela a country which shares similar social and climatic characteristics with the rest of the Caribbean, the oxidation pond system remains the first choice for those cases where there is sufficient space and distance from local communities. In the case of Margarita and Valencia circumstances demanded more sophisticated solutions. Here, a local variation of the activated sludge system has been developed which minimises the need for imported equipment and is consistent with local construction and operation skills limitations. The use of maturation ponds of five days nominal retention time is sufficient to produce high bacterial quality nematode free effluents without chlorination.

The activated sludge systems described in this paper have all been built for less than $20/PE or $80/m^3/day average flow (250 l/day/PE) whilst the lagoon systems cost around $4/PE excluding land in all cases. The electrical energy used in the activated sludge plants is about 3,5 watts per person equivalent of 50g BOD/day which costs about $1,25/PE/year. Operation and maintenance costs come to around $2,00/PE/year making a total annual capital and operating cost of about $5/PE/year, about ten times more than the cost of the lagoon systems but still only 10% of the cost of plants in developed countries. This figure also represents about 1% of the minimum wage for a family group of 5 persons.

The public sector in Venezuela has traditionally suffered from the ills of bloated payrolls, union abuses, uncompetitive salary structure, political interference, under funding of maintenance operations and labyrinthine procurement policies which make day to day consumables purchasing very difficult. However the use of operations contractors at the plants described has assured that they are well maintained as shown by the operating results. The water and sanitation sector remains underfunded however due to political reluctance to apply, charge and collect realistic tariffs and to the idea that the service should receive blanket subsidies from the centre.

References

Baozhen, W. (1987) The Development of Ecological Wastewater treatment and Utilization Systems in China. Wat. Sci. Tech. Vol. 19, N_ 1/2 pp. 51-63

Carbonell, L.M. and Lansdell, M. (1991) Wastewater Treatment and Reuse aspects of Lake Valencia, Venezuela. Wat. Sci. Tech. Vol. 24, N_ 9 pp. 19-30

Lansdell, M. (1987). The Development of Lagoons in Venezuela. Wat. Sci. Tech. Vol. 19, N_ 12 pp. 55-60

Strauss, M. and Blumenthal, U. (1990) Use of Human Wastes in Agriculture and Aquaculture IRCWD Report N_ 08/90, Duebendorf, Switzerland

Wastewater Treatment Systems in Guatemala, Central America

Ing. Adan E. Pocasangre Collazos
Executive Director of the Liquid and Solid Wastes Council, CONAMA, 7a Ave. 7-13 Zona 13, Guatemala, Guatemala
Tel: (502) 440-7916/17, Fax: (502) 440-7938, Home Tel/Fax: (502) 474-3601

Abstract

In Guatemala, Central America live more than 10 million people and exist more than eighty wastewater treatment plants (wwtp), with different types and process. Most of them attend suburban areas, (small communities), others attend private sections of housing projects, and some others industries. Nowadays authorities really don't know exactly the number of wastewater plants existing in the entire country and if they are working correctly. Due to this situation this paper is entitled to get a closer look to the wastewater plants identified and their actual state of maintenance and operation. Also it will show the experience in the use of Trickling Filters in the Republic of El Salvador in Central America.

Introduction

The centralization of populations gives origin to the need of cover the demand of water supply. This situation increase day by day the amount of wastewater flow that is been drained to the sewage pipes without previous treatment. With this situation it is been deteriorating the quality of the streams, rivers, lakes, etc. Most of the industries are draining their wastewaters to the sewage systems without previous treatment contributing to the contamination.

According to the Sectorial Analysis of Water Supply and Wastewater in Guatemala, the served population with sewage pollution control (sanitary sewage and latrines) is as follows:

- Total Population *	10,322
- Served Population	3,142
% Served Population	60%
- Urban Total Population	3,978
- Served Urban Population	2.868
% Served Urban Population	72%
- Rural Total Population	6,344
- Served Rural Population	3,274
% Served Rural Population	52%

* in thousands

Source: Sectorial Analysis of Water Supply and Wastewater in Guatemala - 1994

In Guatemala exist more than 18,000 communities in the whole country where less than 1% have treatment systems for wastewater, discharging about 1,000,000m^3/day of wastewater without treatment at the rivers, lakes, streams, etc.

Actual Situation of Treatment Wastewater Plants

Twenty of the identified wastewater plants have stabilization lagoons units as treatment, in primary or/and secondary treatment. 17 are Imhoff tanks, 12 with Trickling Filters, 4 with UASB (Units Anaerobic Sludge Blanket), and the others with different units. The information shown on the following tables is: location; institution in charge; and if the system is properly working.

No.	Ubicacion	Responsible	Funcionamiento
1	Atescatempa, Jutiapa	Municipalidad	No
2	Caslllas, Santa Rosa	Municipalidad	Si
3	Catarina, San Marcos	Municipalidad	Si (parcial)
4	Flores Costa Cuca, Quet.	Municipalidad	Si (parcial)
5	Guastatoya I	Municipalidad	Si
6	Guastatoya II	Municipalidad	Si
7	Ipala	Municipalidad	Si (parcial)
8	Pajapita	Municipalidad	Si (parcial)
9	Pasaco	Municipalidad	Si (parcial)
10	Patzun	Municipalidad	No
11	Retalhuleu	Municipalidad	Si (parcial)
12	Sanarate I	Municipalidad	Si (parcial)
13	Sanarate II	Municipalidad	Si
14	San Agustin Acasaguast	Municipalidad	No
15	San Esteban Chiquimula	Municipalidad	Si (parcial)
16	San Juan Comalapa	Municipalidad	Si (parcial)
17	Solola I	Municipalidad	Si
18	Tiquisate I	Municipalidad	Si (parcial)

No.	Ubicacion	Responsible	Funcionamiento
19	Tiquisate II	Municipalidad	Si (parcial)
20	Villa Canales	Municipalidad	No
21	Zacualpa, Quiche	Municipalidad	No
22	Nimajuyu	BANVI	No *
23	Bello Horizonte	EMPAGUA	Si (parcial) *
24	Villalobos 1	BANVI	No
25	Villalobos 2	BANVI	No *
26	Mesquital	BANVI	No *
27	Santa Isabel ll	BANVI	No *
28	Justo Rufino Barrios	-	No
29	Peronia, Mixco	Municipalidad	Si (parcial)
30	San Cristobal, Mixco	Municipalidad	No
31	Berlin, Mixco	Municipalidad	No
32	San Jacinto, Mixco	Municipalidad	No
33	USAC (Guate)	USAC	Si (parcial)
34	Villa Hermosa, Villa Can.	Municipalidad	No
35	Ribera del rio, Villa Can.	Lotificadora	Si (parcial)
36	Aurora l y ll	Municipalidad	No
37	Elgin ll	Municipalidad	No
38	Lomas de Portugal, mix.	Municipalidad	Si (parcial)
39	Molino de las Flores, mix.	Municipalidad	Si (parcial)
40	Valles de la Mariposa l y ll	Lotificadora	Si (parcial)
41	Santa Rita, Mixco	Municipalidad	Si (parcial)
42	El Tabacal	Lotificadora	Si (parcial)
43	San Cristobal 2, Mixco	Municipalidad	-

No.	Ubicacion	Responsible	Funcionamiento
44	El Bosque, Mixco	Municipalidad	-
45	Elgin Sur, Mixco	Municipalidad	No
46	Villa Sol, Guatemala	Lotificadora	-
47	Riveras del Pacifico	Lotificadora	-
48	Taxisco, Santa Rosa	Municipalidad	Si (parcial)
49	Calapte, San Marcos	Municipalidad	-
50	Puerto Quetzal	Puerto Quetzal	-
51	Cent. Recreat. Pto. Quetz	Min. de la Defensa	No
52	Base Aerea Sur, Reu.	Min. de la Defensa	-
53	Zona Mil. No. 10/Jutiapa	Min. de la Defensa	-
54	Zona Mil. No. 23/Peten	Min. de la Defensa	-
55	Zona Mil. No. 19/Huehue	Min. de la Defensa	-
56	Zona Mil. Zacapa	Min. de la Defensa	-
57	Santa Elena Barilas, V.C.	Municipalidad	No
58	Central de Mayoreo, Guatemala	Municipalidad	-

The following table shows the wastewater treatment plants that are in construction process in 1998.

No.	Ubicacion	Responsable
1	Tiquisate, Escuintla	Municipalidad
2	Tiquisate, Escuintla	Municipalidad
3	Pajapita, San marcos	Municipalidad
4	El Tesoro, Mixco	Municipalidad
5	Teculutan, Zacapa	Municipalidad
6	Teculutan, Zacapa	Municipalidad
7	Estanzuela, Zacapa	Municipalidad

No.	Ubicacion	Responsable
8	Boca del Monte, V. C.	Municipalidad
9	Camotan, Chiquimula	Municipalidad
10	Camotan, Chiquimula	Municipalidad
11	Taxisco, Santa Rosa	Municipalidad
12	Solola, Solola	Municipalidad
13	Panajachel, Solola	Municipalidad
14	Jocotan, Chiquimula	Municipalidad
15	Jocotan, Chiquimula	Municipalidad
16	San Jose La Arada, Chiquimula	Municipalidad

About the operation, the wastewater treatment plants are working precariously, only 8.7% are working with a removal more than 60% of their capacity. The management of the service is responsibility of the local governments in 65%.

Experience in the Use of Trickling Filters

The use of Trickling Filter in Guatemala like in El Salvador is been popularize lately, due to the topographic conditions (high slopes) and the availability of the use of the land for the location of this unit.

With those systems are reached removals of 40 to 50 mg/lt of BOD using pretreatment by grid and sand removal and primary treatment with sedimentation, secondary treatment with Trickling Filters and Secondary Sedimentation.

The Trickling Filter in this country has been modified changing the entrance device from movable to fixed, due to the difficulty to build or import this device using channels with triangle weirs as distribution system.

The advantages of using the Trickling Filter are Low Maintenance Cost and Operation Simplicity.

Small Community Wastewater Treatment Systems:

Recirculating Filter Technologies; Recent Developments and Applications in Jamaica

Christiane Roy and Grace Foster Reid
Option Environment Inc, 2360 Avenue de La Salle, Bureau 202, Montreal, Quebec H1V 2L1, CANADA
Tel: (514) 257-6380, Fax: (514) 257-6382, Email: croy@opt-env.qc.ca

Intermittent filters are well known domestic wastewater treatment technologies. They are commonly found in rural and periurban areas where they can be used for on-site treatment or community systems. Individual homes, residential developments, resorts, golf clubs, and out of town businesses or industries are examples of potential applications of these technologies. Intermittent filters are septic systems that can be operated as single pass or recirculating systems.

For flows up to 1 000 cubic metres per day, recirculating filters are most appropriate; they are low cost systems both in terms of capital investment and operation. Being septic systems, they include one community or several smaller septic tanks. The septic tank effluent is collected and brought to the treatment site through a small diameter collection network that carries only liquid effluent. The treatment system is comprised of two major components: the recirculation tank and the filter unit. A simple timer controls 0,5 HP pumps that feed the wastewater on the filter through a low-pressure distribution system; the filtered water flows back to the recirculation tank by gravity where a splitter valve directs a portion of the treated water to disposal.

Treatment efficiency is a high quality secondary level with typically 5-day Biochemical Oxygen Demand (BOD_5) and TSS values below 15 mg/L; faecal coliform counts are reduced by two or more orders of magnitude. The treated water can be disposed in a receiving water body or in the soil, depending on local conditions and regulatory requirements. Recirculating filters are simple to operate and require little maintenance.

For individual homes and very small systems with daily flows below 10 m^3/d, single pass systems may be used. These systems do not require a recirculation tank but use a larger filter unit.

Intermittent Textile Filters

Recent developments using non-woven textile coupons as a treatment medium allow a significant decrease in the space requirements for this type of technology, which already compares favourably to other technologies available for community systems (Table 1). Conventional leachfields are designed at loading rates of normally 4 cm/d or less whereas recirculating sand filters can receive 20 cm/d and therefore occupy five times less space.

Recirculating textile filters can be loaded up to 180 cm/d, which represents a further major space reduction. At such high loading rates, mass loading should always be verified. Single pass systems are normally ten times smaller than leachfields.

Table 1: Comparison of Leachfields and Intermittent Filters

Type of System	Typical Hydraulic Loading Rate	Surface Area
Conventional leachfield	4 cm/d	2 500 m^2 for 100 m^3/d
Recirculating sand filter	20 cm/d	500 m^2 for 100 m^3/d
Recirculating textile filter	100 to 180 cm/d	55 to 100 m^2 for 100 m^3/d
Single pass textile filter	40 to 60 cm/d	2,5 to 4,0 m^2 for a home

This space economy is due to the hydraulic properties of the textile coupons. Their water holding capacity combined with their unique porosity made it possible to develop a treatment process based on extended contact times between the wastewater and the biomass that develops and attaches to the treatment medium. As a result, the filter unit becomes a treatment reactor that can be loaded at much higher hydraulic or mass loading rates than filters packed with a granular medium. The surface area can be reduced by a factor of five to nine, depending on treatment goals and wastewater characteristics. For typical domestic wastewater (septic tank effluent BOD_5 = 160 mg/L), and treated water quality with BOD_5 and TSS values lower than 10 mg/L, a space reduction factor of five can be expected.

In order to provide sufficient oxygen for aerobic biodegradation of organic pollutants, forced aeration is a requirement in textile filters. This goal is achieved by using a small ventilator (80 to 100 watts).

Treatment results from one residential unit and one commercial unit are presented below (Table 2). The residential unit treats an average flow of 600 L/d with a single pass textile filter that is 1,5 m_ in surface area and comprised of three 15-cm textile layers. The commercial unit serves a shopping centre. The average daily flow is in the order of 6,8 m^3/d; the wastewater is of a very high strength due to the presence of a meat market on the premises. The treatment system is a recirculating textile filter with six filter modules covering a total of 17,3 m^2; each module is made of three 15-cm textile layers.

Table 2: Textile Filter Treatment Results

System	Flow (m^3/d)	HLR[1] (cm/d)	MLR[2] (g/m^2-d)	BOD_5 (mg/L) Influent Effluent		TSS (mg/L) Influent Effluent		F. coliforms (CFU/100ml) Influent Effluent	
Residential	0,6	41	86	209	5,4	71	5,3	1,35 E5	980
Commercial	6,8	34	121	355	5,4	72	3,6	5,64 E5	2 800

3. HLR = hydraulic loading rate
4. MLR = mass loading rate

Alcan Jamaica's Kirkvine Plant

Another advantage of recirculating filters is the possibility of incorporating other treatment components to meet special treatment needs. A good example is the treatment system recently constructed to treat the domestic wastewater at the Alcan Jamaica plant in Kirkvine. This system is designed to treat 45 m3/d. Due to the new National Resource Conservation Authority sewage effluent standards, strict treatment goals were set for nitrogen in addition to conventional BOD, TSS, and coliform goals (Table 3).

Table 3: Kirkvine Plant Treatment Goals

DBO_5 (mg/L)	TSS (mg/L)	NO_3^- (mg N/L)	Faecal coliforms (CFU/100 ml)
20	20	10	1000

To meet these goals, a recirculating textile filter system was constructed; hydraulic loading rates and recirculation rates on the recirculation system were adjusted to ensure complete nitrification, and a denitrification unit was added in the treatment chain (Figure 2). This last unit receives a carefully balanced mix of septic tank effluent and nitrified water to be denitrified before final disposal. The septic tank effluent serves as carbon source for the denitrification process.

The hydraulic profile of the wastewater treatment process is shown in Figure 3. The raw wastewater is first collected in a community septic tank where solids settle thus reducing the organic load. Anaerobic digestion of the settled solids reduces their volume and allows for long-term accumulation before the tank needs to be emptied. Two biotube effluent filters are installed in the tank near the outlet; the effluent filters capture non-settleable solids that would otherwise be carried forward with the effluent.

With the effluent filters, there are two pumps that pump the clarified effluent in part to the recirculating textile filter tank (RTF tank) and in part to the denitrification textile filter tank

(DTF tank). The RTF tank also receives a portion of the water filtered on the recirculating textile filter (RTF) and all the water from the denitrifying textile filter (DTF).

For this project, a recirculation rate on the RTF of 5,5:1 was chosen. At this recirculation rate, the septic tank effluent is filtered on the RTF 5,5 times before it is removed. The filtered water is split between disposal (1 Q), and the DTF tank (4,5 Q). The water sent to the DTF tank is dosed on the DTF with a recirculation rate of 5:1 and then returns to the RTF tank, thus completing the treatment cycle.

The septic tank is designed for a theoretical detention time of 2,25 days. In the tank are located 2 biotube effluent filters and 2 pumps that are controlled by a timer. A set of floats signal high and low water levels.

The RTF tank has an effective volume 47,6 m^3, i.e. 106% the design flow. In the tank are located four pumps that send the water to the RTF, and a splitter valve that splits the water filtered on the RTF between disposal and the DTF tank. A timer incorporated in a duplex control panel controls the pumps. A set of floats indicates high and low water levels in the tank.

The RTF is designed on a 80 cm/d hydraulic loading rate. It measures 56,9 m^2 and is made of three 15-cm layers of textile coupons. A low-pressure distribution system feeds water uniformly on the surface of the bed. Filtered water is collected at the bottom by a collection pipe.

The DTF tank is a 25 m^3 (effective) concrete reservoir. This tank is smaller than the RTF tank because it need not absorb peak flows. In this tank are located one pump that doses the water on the DTF. A timer incorporated in a simplex panel controls the pump; a set of floats indicates high and low water levels.

The DTF is designed on a 100 cm/d hydraulic loading rate and has a 45-m^2 surface area. A low-pressure distribution system distributes water on the surface of the filter. The filter is a 50-cm bed of textile coupons. At the bottom, two pipes collect the filtered water. This filter is kept saturated by a level control device. A backwash system is also provided.

The Kirkvine plant wastewater treatment system is operational since July 1998. Phase one of the start-up was limited to the RTF cycle. Adjustments were made to ensure proper operation of the system. Daily flows and system performance were monitored; causes of excessive wastewater flows were identified and corrected. Phase two of the start-up concerns the DTF cycle.

Conclusion

Intermittent filters offer attractive wastewater treatment solutions for small flow systems. They are a well-known and widely spread class of technology in North America. Intermittent filters are low-cost systems that are easy to operate, take little space, and provide high quality treatment. They are flexible treatment chains that could incorporate complementary treatment phases such as denitrification, phosphorus removal and disinfecting.

The textile filter options are particularly interesting when granular material is not easily available. Furthermore, the textile filters take less space than the granular beds: a residential unit occupies as little as 4 m^2 while larger systems require 25 times less space than a conventional leachfield. They offer a treated effluent quality with BOD_5 and TSS values below 15 mg/L or less, and faecal coliform counts less than 50 000.

The Kirkvine wastewater treatment plant is an example of how these technologies can be implemented locally.

Small Community Wastewater Treatment Systems In The Wider Caribbean

Francine Clouden
BSc. Sanitary Engineer, Caribbean Environmental Health Institute, PO Box 1111,
The Morne, Castries, St. Lucia
Tel: (758) 452-2501, Fax: (758) 453-2721, Email: fclouden.cehi@candw.lc

Background

The increased supply of potable water together with the growing standard of living and increased industrialization in the Caribbean, including tourism, has resulted in more and more liquid waste (i.e. wastewater) to be disposed of. Considerable attention is therefore now being paid to liquid wastes in nearly all Caribbean countries. Following from this is the realization that liquid wastes are a major source of land-based pollution of the marine environment and therefore pose a significant threat to the integrity of the fragile ecosystems on whose survival the tourist based economies depend.

In most of the countries there is uneven distribution of inhabitants. There is a tendency for the population to be concentrated on the coastal belt because of the need to be close to port facilities, fishing grounds and manufacturing and tourism activities.

In Caribbean countries the capital city is the focus of economic and service activity. There are usually a few additional important centres where populations are concentrated. In many instances there is also development in the suburban periphery and continuous linear patterns of settlement, especially along the coast. The remainder of the population is found in towns, villages and tenantries of varying size.

Providing municipal wastewater treatment for these mainly decentralised communities thus presents a significant challenge to Caribbean Governments.

Sewer systems, exist in some Caribbean countries (e.g. Barbados, Grenada, Trinidad, St. Lucia) In 1991 it was estimated that 10% of the population in the Caribbean is connected to some form of sewer system. Some systems are old, undersized and in need of repair, and many discharge without prior treatment into rivers or the marine environment. New systems are planned in Roseau, Dominica, and the south and west coasts of Barbados. These systems, however, tend to require large capital investments and the planning and implementation stages are very long. There are also numerous small or package plants that are operated by both the public and private sector

By far, the most widely used system of sewage disposal, especially in the urban and peri-urban areas, is the septic tank and soakaway, and in the coral islands like Barbados, the suck well, which is a deep pit to facilitate percolation. In areas where soil conditions do not permit proper infiltration, effluent is generally disposed of in street drains. Many rural communities, especially those without access to piped water supplies, depend upon pit latrines, and the provision of public facilities for wastewater treatment or excreta disposal.

Wastewater Treatment Technologies

Relatively simple wastewater treatment technologies for small communities can be designed to provide low cost sanitation and environmental protection, as well as provide additional benefits such as reuse of treated wastewater. These systems may be classified into three principal types, as shown in Figure 1.

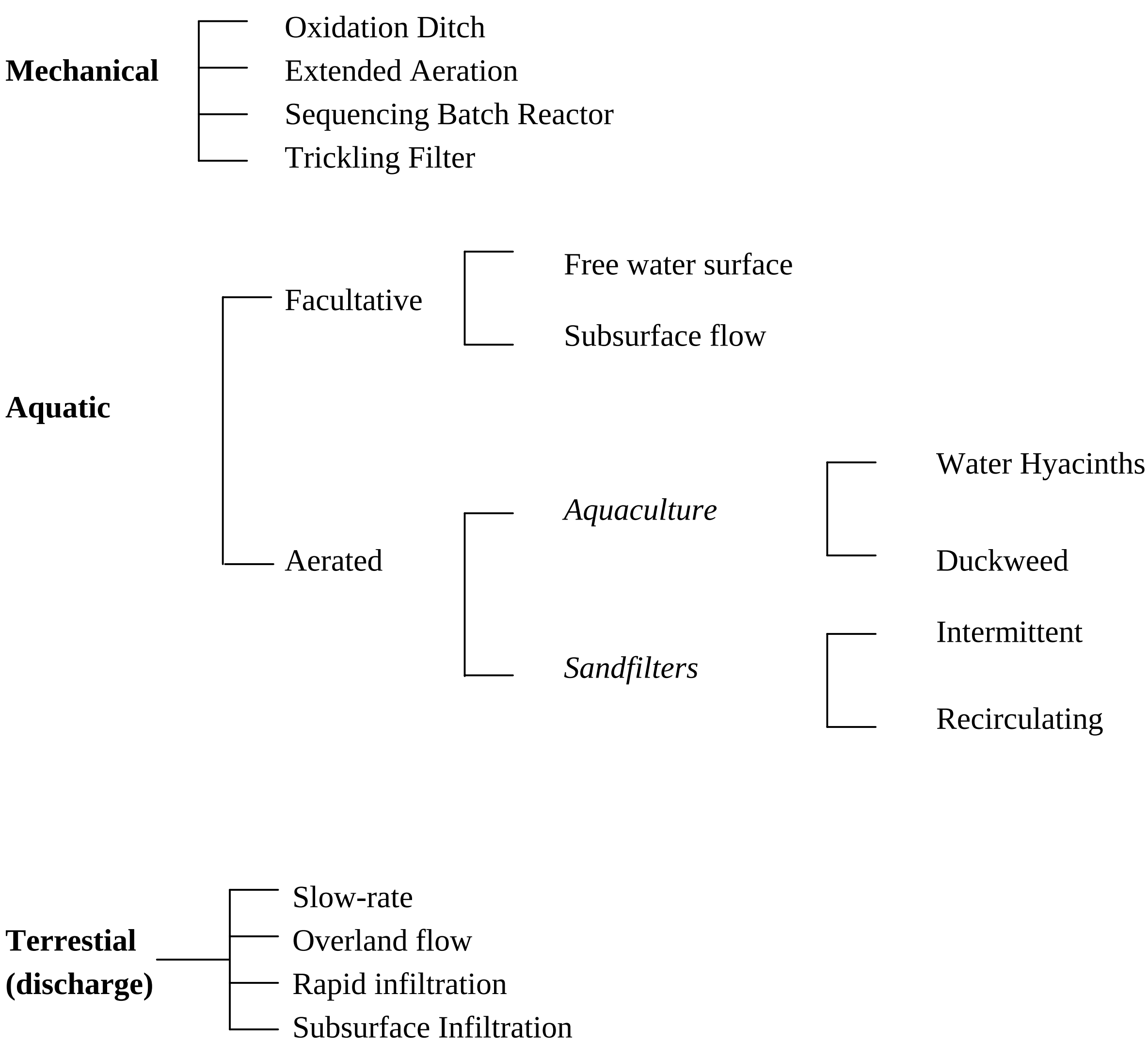

Figure 1. Summary of Wastewater Treatment Technologies

Mechanical Systems

Mechanical systems utilize a combination of physical, biological, and chemical processes to achieve the treatment objectives. Using essentially natural processes within an artificial environment, mechanical treatment technologies use a series of tanks, along with pumps, blowers, screens, grinders, and other mechanical components to treat wastewaters. Sequencing batch reactors, oxidation ditches, extended aeration systems, and contact stabilisation systems are all variations of the activated-sludge process, and are all used with varying success throughout the region, where land is a premium. Most are privately owned and operated, e.g. at hotels, however some communities, most recently in Montserrat do utilise them.

Suitability

These systems are more suitable for places where land availability is a concern, such as residential areas. Both the capital and operational and maintenance costs are generally higher than for the other technologies (depending on the cost of land), but they do afford greater operational control, given that specialized personnel for their operation are available. These systems are designed to meet the limits generally established for secondary treatment (BOD and SS < 30 mg/l) and can also provide advanced treatment.

A study done by CEHI/PAHO in 1991, found that 75% of these "mechanical" type systems were not reaching the minimum generally accepted standards for operation. This was attributed to (1) the use of "high-tech" technology which was not adapted for use in the region; (2) limited understanding of treatment processes by operators; and (3) insufficient time and budget allocation. Recommendations for improvement would include (1) the use of equipment and materials which are locally available; and (2) formal training and eventually certification of operators. Additionally only 16% of the plants surveyed had a trained operator, while a full-time operator was available at only 20% of the plants.

Aquatic Systems

Facultative lagoons are the most common form of aquatic treatment lagoon technology currently in use. The term ‘facultative’ refers to a mixture of aerobic and anaerobic conditions, and in a facultative pond aerobic conditions are maintained in the upper layers, while anaerobic conditions exist towards the bottom. The intermediate layer is aerobic near the top and anaerobic near the bottom, and constitutes the facultative zone. Aerated lagoons are smaller and deeper than facultative ponds and evolved from stabilization ponds.

Constructed wetlands, aquacultural operations are generally very efficient ways to polish a treated wastewater effluent. Constructed wetlands can be utilised in two ways; sub-surface water flow, and surface water flow. These systems use the roots of plants to provide substrate for the growth of attached bacteria which utilize the nutrients present in the effluents, and for the transfer of oxygen. Bacteria do the bulk of the work, although there is some nitrogen uptake by the plants. Typically these systems are long, narrow basins, with depths of less than 2 feet, that are planted with bulrushes or cattails. The surface water system most resembles a natural wetland. The shallow groundwater systems use a gravel or sand medium, which provides a rooting medium for the aquatic plants through which the wastewater flows.

Aquaculture systems are distinguished by the type of plants grown in the wastewater holding basins. These plants are commonly water hyacinth or duckweed. These systems are basically shallow ponds covered with floating plants that detain wastewater at least once per week. The main purpose of the plants in these systems is to provide a secure habitat for bacteria which remove the vast majority of dissolved nutrients. Tables 1 and 2 summarise the design features of these systems.

Table 1. Typical Design Features for Aquatic Treatment Units

Technology	Treatment Goal	Detention Time (days)	Depth (feet)	Organic Loading (lb/ac/day)
Oxidation pond	Secondary	10-40	3-4.5	36-110
Facultative pond	Secondary	25-180	4.5-7.5	20-60
Aerated pond	Secondary, polishing	7-20	6-18	45-180
Storage pond	Secondary, storage, polishing	100-200	9-15	20-60
Root zone Treatment Hyacinth pond	Secondary	30-50	<4.5	<45

Table 2. Typical Design Features for Constructed Wetlands

Design Factor	Surface Water Flow	Subsurface Water Flow
Minimum Surface Area	23-1 IS ac/mgd	2.3-46 ac/mgd
Maximum water depth	Relatively shallow	Water level below ground surface
Bed depth	Not applicable	12-30 in.
Minimum hydraulic residence time	7 days	7 days
Minimum pretreatment	Primary (secondary optional)	Primary
Range of organic loading as BOD	9-18 lb/ac/d	1.8-140 lb/ac/d

These systems are being used to a small extent in the region. Two hotels (one in St. Lucia, the other in Grenada) are currently using aquaculture systems, utilizing the water hyacinth, with reasonable success. CEHI as recently as 1995 completed a design for a constructed wetland at another hotel in St. Lucia, (which has not been constructed to date) and has given preliminary advice to a third on a similar system. The University of the West Indies, Mona, Jamaica is currently operating a pilot system.

Suitability

Natural treatment systems are capable of producing an effluent quality equal to that of mechanical treatment systems, and can meet the secondary treatment limits. These systems are extremely applicable where there is plenty of land available, and where suitable aquatic plants grow naturally. Most advantages of this system relate to their "low-tech/no-tech" nature, which means that these systems are relatively easy to construct and operate, and to their relatively low cost, which makes them attractive to communities with low budgets. However their simplicity and low cost may be deceptive in that the systems require frequent inspections and constant maintenance to ensure smooth operation. Concerns include hydraulic overloading, excessive plant growth, and the fact that they can produce effluents of variable quality depending on time of year, type of plants, and volume of wastewater loading.

Terrestrial Treatment Technologies

These include slow-rate overland flow, slow-rate subsurface infiltration, and rapid infiltration methods, which are used for further polishing. Additional benefits are the yielding of water for groundwater recharge, reforestation, agriculture, and/or livestock pasturage. They depend upon physical, chemical, and biological reactions on and within the soil. In slow-rate systems, either primary or secondary treated effluents are applied at a controlled rate to a vegetated land surface of moderate to low permeability. The wastewater is treated as it passes through the soil by filtration, adsorption, ion exchange, precipitation, microbial action, and plant uptake. Vegetation is a critical component of the process and serves to extract nutrients, reduce erosion, and maintain soil permeability.

Slow-rate subsurface infiltration systems (e.g. soak-away) and rapid infiltration systems (e.g. suck-wells in Barbados) are "zero-discharge systems" that rarely discharge effluents directly to streams or other surface waters, but can recharge groundwater aquifers. In overland flow systems the effluents are eventually discharged to surface water. The main benefits of these systems are their low maintenance and low technical manpower requirements.

Suitability

Sub-surface infiltration systems are designed for municipalities of less than 2,500 people. They are usually designed for individual homes, but can be designed for clusters of homes. Although they do require specific site conditions, (see Table 3) they can be low-cost methods of wastewater disposal.

Table 3. Site constraints for Land Application Technologies

Feature Flow	**Slow Rate**	**Rapid Infiltration**	**Subsurface Infiltration**	**Overland**
Soil Texture	Sandy Loam to Clay Loam	Sand and Sandy Loam	Sand to Clayey Loam	Silty Loam and Clayey Loam
Depth to Groundwater	3 ft	3 ft	3 ft	Not
Vegetation	Required	Optional	Not Applicable	Required
Climatic Restrictions	Growing season	None	None	Growing Season
Slope	<20%, cultivated land <40%, uncultivated land	Not Critical	Not Applicable	2% - 8% **Finished** Slopes

Source: USEPA, *Wastewater Treatment/Disposal for Small Communities.* Cincinnati, Ohio, 1992. (EPA Report No. EPAZ25/R-92 005)

Excreta Disposal Technologies

Many small communities in the Caribbean do not have wastewater collection or treatment systems, especially where potable water supply is limited. The challenge in this case is to provide an adequate system for excreta collection, disposal and possibly treatment at another location. Some of the more common systems are outlined below.

Pit Latrines

Pit latrines are the simplest and most widely distributed disposal plants for excreta. They can be utilized not only in rural/rustic areas, but also in municipal districts. These plants are at the same time the cheapest systems for any self-help programs.

A simple pit latrine. The excreta falls directly into an excavated pit which normally is neither consolidated or lined with brickwork. All liquids like urine, cleaning water, etc. can seep into the subsoil. The solid substances are retained and will gradually fill up the pit. As soon as two-thirds of the pit is filled, it either has to be emptied or a new pit dug.

Modifications to this simple pit latrine include the ventilated improved (VIP) latrine, with or without offset pit; the water-flush or pour-flush latrine.

Planning Aspects

The following factors have to be taken into consideration when designing pit latrines:

1. Population density
2. Groundwater level
3. Consistency of the subsoil
4. Water pollution

Institutional Aspects

The construction of pit latrines is quite simple and should therefore be carried out as far as possible by self-help. The biggest problems are encountered in areas where latrines had previously been unknown, or previous systems had not functioned well. In some peri-urban areas there may also be a social stigma attached to pit latrines.

In these cases the local administration should mount a public awareness and education programme outlining the needs and benefits of the systems, how they should be used effectively, and measures regarding the design standards, credit terms and financing. The installations should be checked several times to inspect utilization and maintenance.

Composting Toilets

In principle there are two different types of composting toilets.

Batch composting toilets are usually built up with a two-pit system. As soon as one pit is filled up to two-thirds, it is topped up with earth and closed, the second one is then used. When the second one is filled up, the first one has to be emptied and put into service. This type of toilet provides an anaerobic composting.

For continuous composting only one pit is required and it must be completely bricked up. All the excreta, grass, straw, sawdust ashes etc. fall onto the grates, which are spaced by narrow slits and compost there. The digested materials finally fall into the humus pit and have to be removed at regular intervals. These systems do have high maintenance expenditure, and it has not been completely established under what conditions the composting process could proceed in the best possible way. They are generally not recommended for use in the tropics.

Aqua privies and Septic Tanks

In the absence of public disposal installations, septic tanks, besides pit latrines are the most common installation for simultaneous disposal of excreta and household wastewater. These tanks have the distinct advantage that they can be connected later on to any public network. The tank will then serve for a certain preliminary treatment preventing a large quantity of solids from flowing into the sewerage system (see Alternative Collection Systems).

Aqua privies generally have a lower purification capacity than septic tanks. They consist of one compartment which is dimensioned on the basis of 0.12 m3 per user, with a maximum capacity of 1m3. This means that sludge must be removed every 2 to 3 years. If there is a sufficient water supply and/or sewerage possibilities, for hygienic reasons preference should be given to the septic tank.

Bucket Latrines/Vault Toilets

The design of toilets with collection pits (vault toilets) resembles in general that of the pour-flush toilet. Construction costs are low, as no excavation work is involved, Space requirements are small, and this is the main reason why such plants are frequently built in densely populated areas.

The excreta must then be disposed of either individually, by the user, or through a community collection and disposal system (which is preferred). This type of system has many health risks inherent in it. The buckets can easily overflow and pollute the environment and expose users to disease causing organisms. Buckets must also be kept clean after being emptied to reduce the attraction of flies and other vectors.

This system is currently in use in at least two villages in St. Lucia, with varying success, as discussed in a later section.

Communal Sanitation Facilities

These are facilities built in blocks and installed in central areas. As a rule they are connected to septic tanks which are designed according to the number of toilets and equipped with running water. They may also provide showering and laundering facilities.

There are generally two types of communal facilities

1. Blocks which are used only by a certain number of families
2. Common installations which are frequented by all inhabitants of a community depending on their need.

The latter is what commonly obtains in the Caribbean.

Alternative Collection Systems

Small diameter gravity sewers are rapidly gaining popularity in unsewered areas because of their low construction costs. Unlike conventional sewers, primary treatment is provided at each connection (septic tanks), and only the settled wastewater is collected. Grit grease and other troublesome solid which may cause obstructions in the collector mains are separated form the main wastewater flow and retained in interceptor or septic tanks installed upstream of each connection. With the solids removed, the collector mains need not be designed to carry solids as conventional sewers must be.

Large diameter pipes designed with straight alignment and uniform gradients to maintain self-cleansing velocities are therefore not necessary. Instead the collector mains may be smaller in diameter and laid with variable or inflective gradients. Construction costs are reduced because SDGS may be laid to follow the topography more closely than conventional sewers and routed around most obstacles in their path without installing manholes.

Such a system had been considered for a rural community in St. Lucia, but was never fully designed or constructed.

An Exercise in Appropriate Technology – Case Study of a Typical Village in St. Lucia

The village is located on the East Coast of St. Lucia. The soil type is extremely rocky in some areas and the ground water table is high, as the main part of the villages is located in a flood plain close to the ocean. Houses are located very close to each other and the development is random and unplanned.

The total population of the village is 4440 (1992 census) with a total number of households of 1179.

St. Lucia Water and Sewerage Authority (WASA) supplies the potable water, with intakes located in the vicinity. Treatment consists of a stone filter, sand filters (in parallel), and chlorination. 23% of the population are supplied by standpipes in the neighborhood, 50% have a private supply (i.e. piped water in the home) and 27% have none available close by i.e. no standpipe within walking distance. Because of the topography regularity of the supply is compromised.

Current excreta disposal practices are as follows: 11% pit latrines; 13% pail latrines; 34% water closet and septic tank; 42% none on premises. This forty-two percent of the residents (600 persons) use the public facilities provided of which there are five with a total of 22 toilets and 24 showers operational.

Most of the facilities were built 15 to 20 years ago and include showering and laundering facilities. All the facilities operate with the same system. The grey water is discharged either directly into the sea or into a surface drain that runs into the sea. Excreta ("black water") is treated in a septic tank. The effluent from the septic tank is disposed of into a soakaway through a pipeline. A pump truck is used to remove the sludge remaining in the septic tank. The regularity of this is dependent on the availability of the pump truck, which is sporadic due to frequent breakdowns.

At one of the facilities located at the beach the use of the toilets was discontinued in order to avoid pollution caused by a crack in the pipe of the septic tank and the proximity of the corresponding soakaway to the sea. Bathing in the 4 shower rooms and laundry is still practiced and the grey water goes directly into the sea.

The newest facility, built in 1994, near the fishing port of the village is in comparatively good condition. It is equipped with 8 toilets and 8 shower rooms. As the caretaker reported the only problem encountered is frequent breaking of the toilets cisterns because domestic fittings have been used.

Another facility is elevated, therefore some problems are encountered with its water supply. At certain times, especially in the morning the water supply fails in the whole facility.

The remaining two facilities are working well. Both are centrally located, where most of the houses have no private amenities.

Moreover the two facilities at the beach have night soil chutes to prevent the residents from throwing their night soil into the river. Unfortunately the use of the night soil chutes had to be discontinued due to the residents disposing of solid waste into them. This led to frequent choking which caused the maintenance cost to rise. Additionally, the instruction board for proper use of the chutes has gone missing from one of the facilities.

Most of the public facilities have in common that they are not maintained properly, have often fallen into disrepair and are subject to vandalism by the residents.

The result of most of these problems is that the village has a high incidence of diarrhea and other enteric diseases such as Typhoid Fever and Dysentery. A recent survey (stool examinations) revealed that 65% of the school age children in the village were infested with some type of Helminthes. Monitoring of the potable water supply over a two-and-a-half week period during the rainy season showed that the quality of drinking water was quite good. The conclusion may be drawn therefore that poor sanitation, hygiene and excreta disposal are the main causes of the high incidence of disease.

The systems currently being used in the village are all deemed "appropriate technology" yet they still failed. The information just presented suggests that the problem in the village cannot be solved solely by a technical approach such as construction of Pit Latrines or improvement in water supply. It would be relatively simple to recommend and design such. Other short-term solutions such as repair and rehabilitation of public facilities can also be implemented but a more holistic approach involving all stakeholders needs to be adopted. The previous failure of the other projects, such as the night soil chutes and the lack of regard of residents towards the public facility need to be examined and addressed before any solution can be successfully implemented.

The practices of the reverting to using the bushes or rivers when the water supply is bad indicates a general lack of understanding on the part of residents of basic sanitation and hygiene issues, and their link to the incidence of illness and diseases.

We can therefore conclude that the term "appropriate technology" should refer not only to the technical solution but should encompass a complete system that addresses social, cultural and economic issues.

References

Clouden, F; Joel, D; Singh, J; Wastewater Treatment and Excreta Disposal in Tropical Rural Areas – A Case Study of Health Implications

GTZ/GATE; Wastewater Treatmnent and Excreta Disposal in Developing Countries; March 1980

Mara, D; Sewage Treatment in Hot Climates;

PAHO/CEHI; Assessment of Operational Status of Wastewater Treatment Plants in the Caribbean; December 1992

Sweeney, Vincent; Wastewaters and their Treatment in the Caribbean; July 1995

Sweeney, Vincent and Kraft, Harald; Rootzone Wastewater Treatment in St. Lucia; April 1995

UNEP; Sourcebook of Alternative Technologies for Freshwater Augmentaion in Latin America and the Caribbean

USEPA; Alternative Wastewater Collection Systems

USPA; Wastewater Treatment/Disposal for Small Communities; September 1992

Decision-making Software and Information Systems:

"maESTro"

Vicente Santiago Fandino
Programme Officer, Shiga Office, 1091 Oroshimo-cho, Kusatsu City, Shiga 525-0001, Japan
Tel: (81-77) 568-4585, Fax: (81-77) 568-4587, Email: vstiago@unep.or.jp

Introduction

a. UNEP International Environmental Technology Centre (IETC)

IETC's main role is to promote the application of Environmentally Sound Technologies (ESTs) to address urban environmental problems, such as sewage, air pollution, solid waste and noise, and the management of freshwater basins in developing countries and countries with economies in transition. The Centre serves as a proactive inter-mediator for cooperation between sources and users of ESTs.

b. Definition of ESTs

Environmentally Sound Technologies (ESTs) encompass technologies that have the potential for significantly improved environmental performance relative to other technologies. Broadly speaking, these technologies protect the environment, are less polluting, use resources in a sustainable manner, recycle more of their wastes and products, and handle all residual wastes in a more environmentally acceptable way than the technologies for which they are substitutes.

Furthermore, as argued in Chapter 34 of Agenda 21, ESTs are not just "individual technologies, but total systems which include know-how, procedures, goods and services, and equipment as well as organizational and managerial procedures". Consequently, when considering technology promotion, IETC's approach incorporates both the human resource development (including gender relevant issues) and local capacity building aspects of technology choices. ESTs should also be compatible with nationally determined socio-economic, cultural and environmental priorities and development goals.

> *Information on ESTs, however, is often hard to obtain in a standardized, user-friendly format. To solve this problem, IETC created a searchable electronic EST-directory, called maESTro.*

maESTro - EST Directory

a. What is maESTro?

maESTro is an information tool that links providers of environmental technology with potential users. maESTro's database contains more than 1500 worldwide information on a full range of environmental technologies, institutions and information sources including air and water pollution, environmental management, human settlements, recycling toxic substances, solid waste, wastewater, water augmentation and more. The information is regularly updated by IETC as well as EST contributors, individual users, organizations and institutions.

maESTro was first developed as a tool to disseminate information on Environmentally Sound Technologies (ESTs) on floppy disks, CD-ROMs and hard- copy format for free of charge. In March 1998, in response to maESTro user's request, IETC has decided to further develop maESTro on the worldwide web so that people can access through the Internet. The newly developed web-maESTro can be found at the EST Directory on IETC's homepage (http://www.unep.or.jp).

The purpose of the database is to be used as a directory of environmental technologies and to present as many options as possible. The user should then contact the technology owners/institutions/information sources and obtain additional data.

b. EST Contributors

Since 1996, maESTro has been honored to partner with numerous government ministries, including the Ministry of Environment in New Zealand, the Ministry of Nature & Environment in Mongolia, the Ministry of Environmental Protection in Lithuania, the Ministry of Environment & Forests in India, the Ministry of Housing, Municipality & Environment in Bahrain, the Ministry of Environment in Lebanon, the Ministry of Energy & Mines in Eritrea, and the Ministry of Environment of the Republic of Korea.

Efforts have been focused on negotiating with potential environmental information contributors in both the public and private sector to develop the exchange of EST-related information. Among the numerous contributors to maESTro have been UNIDO and GEC (Global Environment Centre Foundation) in Japan, EPA (Environmental Protection Agency) in the United States, and OCETA (Ontario Centre for Environmental Technology Advancement) in Canada (see Table 1).

Table 1. EST Contributors

A	Argentina	- Mr. Eduardo Sendra, Instituto de Limnologia Dr. Raul Ringuelet
	Austria	- Mr. Peter Pembleton, UNIDO
C	Canada	- Mr. David Pederson, Corporations Supporting Recycling (CSR) - Prof. Ray Cote, Dalhousie University
	Chile	- Ivan Tobar Guerrero, INTEC
	Colombia	- Mr. Edgar Castillo, Universidad Industrial de Santander
	Czech	- Mr. Daniel Svoboda, AGSS Ltd
	Ecuardo	- Mr. Marco Encalada, Corporcion Okios
	Egypt	- Dr. Mohamed A.E. Badri, University of South Valley
G	Germany	- Dr. Jorg. W. Fromme, International Transfer Centre for Env*tal Technology (ITUT),
	Greece	- A.I. Zouboulis, Aristotle University
H	Hungary	- Mr. Zsolt Istvan, Bay Zoltan Foundation for Applied Research Institute of Logistics and Production Systems
I	India	- Dr. D. Narasimha Reddy, Centre for Resource Education (CRE) - Mr. Harjit Singh, Ministry of Environment and Forests - Mr. Vadim Kotelmikov, APCTT
J	Japan	- Mr. Kaoru Sasabe, Ministry of Construction - Mr. Shinichi Arai, Global Environmental Centre Foundation - International Environmental Technology Center - Mr. Yoshio Shimazu, ILEC (International Lake Environment Committee) - Ms. Kani Keiko, International Centre for Environmental Technology Transfer (ICETT)
	Jordan	- Mr. Ayman Al-Hassan, Royal Scientific Society
K	Kenya	- Ms. Maria Arce, Environment Liaison Centre International (ELCI)
	Kiribati	- Mr. Eita Metai, Work & Energy
	Korea	- Mr. Sang-Ho Lee, Korea Institute of Industry & Technology Information - Mr. Younghan Kwon, Korea Environmental Technology Research Institute (KETRI)

L	Lybia	- Dr. M.A. Muntasser, International Energy Foundation
M	Malaysia	- Mr. Goh Kiam Seng, Centre for Environmental Technologies (CETEC)
P	People's Republic of China	- Ms. An Tong, National Environmental Protection Agency (NEPA) - Ms. Jiang Xiaoyu, China Association of Environmental Protection Industry - Prof. Huang Xia, Tsinghua University
	Philippines	- Mr. Danilo G. Lapid, Centre for Advanced Philippine Studies
	Poland	- Ms. Beata Michaliszyn, Institute for Ecology of Industrial Areas
S	Switzerland	- Annette Pruss, World Health Organization - Dr. Niklaus Klaentschi, EMPA, Swiss Federal Laboratories for Materials Testing and Research - Mr. Dieter Koenig, UNCTAD
T	Thailand	- Ms. Lilia R. Austriaco, Asian Institute of Technology (AIT)
U	Ukraine	- Mr. Anatoliy I. Salyuk, Ukrainian State University of Food Technologies
	United States of America	- Mr. William McSpadden, Global Environment & Technology Foundation - Dr. Nicholas Ashford, MIT - Tad McGalliard, Work & Environment Institute
	United Kingdom	- Dr. Chris Watts, WRc
	Uruguay	- Mr. Alexis Ferrand, Environmental Management Secretariat (EMS)

c. Data in maESTro

All information collected and disseminated through maESTro remain under the full responsibility of the original source of information. No guarantee is given, nor responsibility taken by IETC for errors or omissions in the Directory, and IETC **does not accept liability** for any information or advice given in relation to or as a consequence of data contained in our information system.

IETC's mandate is to function as proactive intermediator between providers and users of ESTs and/or related information by bringing together all interested parties. IETC **does not endorse** particular technologies disseminated through this Directory as environmentally sound. That is the discretion of maESTro users.

d. maESTro Categories

The data in maESTro are categorized into three fields: Technology, Institution, and Information System (Figure 1).

- Technology: "hard"[4], "soft"[5] and indigenous[6] environmental technologies in the world.
- Institution: a compilation of currently about 460 institutions worldwide dealing with ESTs
- Information System: information tools (i.e. data bank, directory) that supply information on ESTs

Users can browse the information through three query parameters: keywords (wastewater, treatment, etc.), geographical location and INFOTERRA themes.

Dissemination of Information through maESTro

maESTro is available on- line through the Internet. For those who do not have access to the Internet, IETC provides maESTro in the form of CD-ROM (called PC maESTro), floppy disks and/or hard-copy format on specific issues.

a. Hard-Copy Format

Hard-copy format of maESTro is provided to users upon their requests **free of charge** (Figure 2). The hard- copy maESTro includes: Preface, Table of Contents, EST directories on the request, and Index by INFOTERRA themes and Location.

b. CD-ROMs and Floppy Disks

maESTro is also available in CD-ROMs and/or floppy disks (Figure 3). Users can browse, modify, insert, import and export data with their PCs. The system is user-friendly, and with just a click on the mouse, the information appears in a standardized format called Directory Interchange Format (DIF). Through DIF, maESTro is fully compatible with major international databases such as UNEP's Global Resources Information Database (GRID), NASA, CEOS and NASDA.

The information in CD-ROMs and floppy disks is regularly updated by IETC, and the latest version of CD-ROMs and floppy disks are provided to registered users free.

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[4] Hard technologies include equipment(s) and devices(s); i.e. water treatment and supply technologies, sewage and waste treatment facilities, ground remediation technologies and pollution monitoring equipment.

[5] Soft technologies refer to planning and management techniques (such as Environmental Technology Assessment, Risk Assessment and Environmental Auditing) that provide the contextual framework within which "hard" technologies should be understood.

[6] Indigenous technologies refer to the traditional technologies produced by local communities in a given environment

c. Internet (web-maESTro)

The web-maESTro enables all Internet browsers to log in for free anytime in search of environmental information and to browse the latest data in a timely and direct fashion (http://www.unep.or.jp/maestro/). The data is updated on the daily basis by IETC. Furthermore for the better understanding, images are attached to some information.

Although registration is not mandate, IETC recommends users to register into maESTro for their convenience (registration is free). Followings are the advantages entitled to the registered users.

- Personalized information
  On the welcome page of maESTro, you will see how many new and updated information has been entered since your last visit.

- Notification by e-mail
  For your convenience, whenever there is a major change in maESTro system, you will be notified by e-mail.

- Insert and modify the data
  Users can Insert and modify their own information into the maESTro database. Users who have inserted new data can keep, preview, modify and delete their data in the Personal Database until the data is completed satisfactorily and is ready to be sent to IETC for verification.

Furthermore, maESTro offers a working group facility that enables users and their partners to work together using network system. This means that users can share, view, and modify information from different users in the same working space.

Benefits for maESTro Users

- **Free of Charge**

  Through maESTro, users are able to become part of IETC's EST-directory for free. This directory is growing rapidly through increased number of IETC's networking partners as well as individual Internet users in the world. As more and more maESTro becomes widespread, information exchange will become more feasible.

- **Global Networking**

  All the users (individuals, organizations and companies) can browse, insert and modify their own data at their own location through web, e-mail, and/or mail (floppy disks for those without Internet access). The data inserted by users will be verified by IETC and soon be disseminated globally through maESTro.

Contributions to maESTro

All information in maESTro will be continuously amended and updated. For this purpose, technology owners and other interested institutions are welcomed to add their EST information on ESTs to this EST Directory. Assisted by maESTro, each institution can manage their internal information collection and exchange. All entries made will be accessible throughout a global network of EST information suppliers and users, and also linked to UNEP/IETC Homepage for Internet browsers.

Please address your queries and requests regarding maESTro to:

UNEP/IETC Shiga Office
Oroshimo-cho, Kusatsu City,
Shiga, 525-0001, Japan
Tel: +81 775 68 4580
Fax: +81 775 68 4587
E-mail: maestro@unep.or.jp
URL: http://www.unep.or.jp/maestro/

WAWTTAR

Christopher McGahey, Ph.D.
USAID/Jamaica Coastal Water Quality Improvement Project (CWIP), USAID Environmental Health Project (EHP), ARD Inc.
110 Main Street, Fourth Floor, Burlington, Vermont 05401, cmcgahey@ardinc.com

Introduction

The WAWTTAR program was designed to assist financiers, engineers, planners and decision-makers in improving their strategies toward sustainable water and sanitation coverage while minimizing impacts on water resources. The program is built upon the concept that when equipment or technology is supplied, access to repair parts and resources for operation and maintenance are available. This includes having materials, equipment and trained operators to ensure that the environmental and financial investments are protected.

Involvement of the target population from the early stages in a water supply and wastewater treatment project is crucial for long-term success. Local decision-makers at all levels need to understand the basic principles of the various processes and support the ideas introduced. The WAWTTAR program is intended to be used as a tool to support effective decision-making. It was developed specifically for application at the pre-feasibility stage of project development to assist planners select suitable water and wastewater treatment processes which are appropriate to the material and manpower resources available in their particular location at particular times. The breadth of coverage of the software is aimed at eliminating the problem of overlooking applicable treatment processes and minimizing system failures due to installation of inappropriate treatment technologies.

The WAWTTAR program is intended to be applied in the early evaluation of potential infrastructure investments in the areas of water treatment, wastewater treatment and water reclamation. The program is designed to assist decision-makers dealing with the following types of issues:

1. Identification of the least-cost treatment scheme for a community with site-specific socio-economic and geographical conditions;
2. Presentation of risks to long-term sustainability of selection of identified treatment schemes;
3. Collection of viable combinations of technologies available to a specific community to meet water reuse standards or guidelines;
4. Identification of least-cost wastewater collection and treatment options for high-density, peri-urban communities;
5. Balancing of coverage and risk for selection of treatment schemes within financial constraints;
6. Selection of technologies to meet particular water quality and/or reclamation standards; and

7. Sensitization of decision-makers to the issues of sustainability related to water, sanitation, wastewater and/or water reuse.

Technology Selection

The main use of WAWTTAR is as a tool for individuals with a technical background to screen and investigate possible water and wastewater treatment options. It enables the user to accomplish this by examining the public health status, water resource requirements, material availability, cost structures and ecological conditions which exist in a particular community. The program assesses these combined factors to generate a set of comparable and refinable feasible technical solutions.

WAWTTAR incorporates innovative and alternative technologies and emphasizes water reuse as an integral component of treatment schemes. WAWTTAR does not, however, exclude conventional options and is of equal usefulness in the screening and examination of such options as well. The main application of WAWTTAR is in technology assessment and evaluation for urban population centers with significant human, material and financial resources available for infrastructure improvement. In most of these urban centers, access to adequate sanitation is typically available for most residents through sewers or individual septic tanks.

For many others, especially those living in peri-urban zones, residents are typically without acceptable wastewater collection and treatment systems. What systems do exist in these communities generally follow conventional designs although alternative systems may be applicable. WAWTTAR has also been designed to account for the particular, non-conventional wastewater collection and treatment systems which are applicable to these types of settings.

Operation of WAWTTAR

WAWTTAR requires an IBM-PC compatible computer running Microsoft Windows 95 or later. Thirty-two MB of RAM and a minimum graphics resolution of 800x600 with 256 colors are required to run the program. Depending upon individual computer configuration, between 30 and 40 MB of disk space are required to install WAWTTAR. It is intended to be installed on a computer from a CD-ROM disk.

In the basic operation of WAWTTAR, fundamental parameters such as performance standards, material costs, raw water or wastewater quality, community needs and capabilities, and planning horizons are entered by the user into easily editable data fields. The user then constructs several possible sequential treatment schemes from a comprehensive list of available treatment processes contained in the software program. WAWTTAR first screens these options according to the needs, capabilities and resources of the community in question, and it discards those options which are infeasible. WAWTTAR then calculates the performance, construction costs and operations and maintenance costs of the remaining viable treatment schemes. These calculations are based on simple mathematical models of each of the treatment processes. Feasible options can then be compared based on performance and annualized costs.

For each infeasible treatment scheme, WAWTTAR displays the reasons for infeasibility. The user can, therefore, analyze infeasible treatment schemes for deficiencies and reassess or vary the criteria which led to failure. These deficiencies can be corrected and the cost and performance of the corrected system can be calculated for consideration against other feasible alternatives.

WAWTTAR is not a dynamic program and does not directly analyze the response of a given system to, for example, variable influent conditions. Sensitivity to varying influent values must be explored by multiple trials of treatment systems with different influent qualities. WAWTTAR also does not assemble the sequential treatment schemes to be evaluated. The building of these schemes must be done as part of the application of WAWTTAR by a user familiar with the processes and their general capabilities.

WAWTTAR is intended for use on actual field water and wastewater treatment and reuse problems. Extensive efforts have been made to provide accurate cost and performance data which are applicable for a wide range of real world applications. The user should, however, validate the reasonableness of all construction cost, operational cost and performance data for all processes relative to the actual settings of the application.

Data Collection

The principal strength of WAWTTAR as a tool to support effective decision-making is its ability to accept and consider a wide range of site-specific data in developing the sets of feasible and infeasible solutions for wastewater collection and treatment. WAWTTAR presents numerous tables in which the user is required to supply information. These tables serve not only as inputs to the software, but also as guides for planners and decision-makers regarding the range and quality of information which should be considered in the development of infrastructure initiatives. A thorough consideration of all informational components will ensure that issues ranging from material availability to the presence of spares and institutions to ensure sustainability are incorporated into planning and pre-feasibility analysis.

Community Data

The principal set of data which the user must individually input are those which are site-specific to the location being considered for infrastructure improvement. These data are intended to describe the conditions under which the proposed project is to be implemented. These should be collected collaboratively with local leaders, planners and engineers. These community data are divided into several categories as displayed below:

1. General
    - Community identification
    - Community location
    - Stakeholders

2. Demographic

    - Population, density and growth rate
    - Household size
    - Spatial growth
    - Current and projected water use
    - Current and projected wastewater production

3. Resources

    - Availability of construction, operation and maintenance equipment and materials
    - Energy and labor resources
    - Availability of chemicals, media and laboratory services

4. Hydro-meteorological

    - Precipitation and evaporations rates
    - Surface temperatures and frost lines
    - Raw water and wastewater quality
    - Point source inputs
    - Collection system description

5. Financial

    - Planning horizons
    - Exchange rates
    - Interest, discount and inflation rates
    - Construction and O&M cost indices
    - Land values

6. On-site

    - Soil and ground types
    - Depth to water table
    - Isolation distances from relevant features
    - Dwelling types
    - Defecation practices
    - Gender issues
    - Accessibility and waste hauling practices

This wide range of categories includes many which are frequently overlooked. The capacity of responsible institutions, for example, has a major impact on what technologies are feasible to use. A complex and highly technological treatment system may be a viable option in terms of influent characteristics and treatment requirements, but such a system is likely to fail in remote areas or where there is little in the way of government support or training opportunities.

The availability and cost of resources can dramatically affect the feasibility of treatment and reuse options in every project stage from construction to operation and maintenance. Resources in the case include the type and reliability of power supply, manpower from simple unskilled labor to technical and professional personnel, treatment chemical availability, and any other type of human or physical capital that might be necessary.

Additionally, social factors of the community in question are of high importance but are infrequently recognized. Local attitudes and norms regarding defecation, waste handling, gender relations, preferred dwellings and family structure can affect design criteria ranging from raw wastewater quality to the types of technologies which are acceptable and likely to be used by community members. Failure to adequately characterize and account for these factors in planning and design can result in the selection of inappropriate technologies, and ultimately in the failure of a treatment system regardless of how well designed from a physical and technological standpoint.

Treatment Process Data

The second type of data utilized by WAWTTAR are Treatment Process Data. The main purpose of the process data tables in WAWTTAR is to provide information on the capabilities, physical and cultural limitations, costs, resource requirements and possible environmental impacts of water and wastewater treatment and reuse processes. Such information for nearly 200 water and wastewater treatment processes is provided in the WAWTTAR database. All of the data associated with each process is available for review by the user as a reference to help with the user's understanding of the applicability of each process. In addition, while the list includes a wide range of processes, users can easily add new processes to take into account factors such as local conditions and new technologies.

For each process, a set of tables contains information that defines the characteristics of the process. The tables and their content are shown below:

1. General

    - Type of process
    - Identification of descriptive files for process

2. Construction

    - Equipment, energy, labour and material requirements
    - Construction costs relative to hydraulic, solids and organic loadings
    - Economic life span of process

3. Operation and Maintenance

    - Land requirements relative to hydraulic, solids and organic loadings

    - Equipment, chemical, media, laboratory and material requirements

- Process control and energy needs
- Operation and Maintenance costs relative to hydraulic, solids and organic loadings
- Solids production rate and moisture content
- Allowable influent quality values
- Removal efficiency for influent constituents
- Adaptability of process to upgrading, flow variations and influent quality

4. Siting

- Allowable precipitation and surface temperatures
- Required surface soil types and percolation rates
- Necessary horizontal and vertical isolation distances

5. Impacts

- Nutrient management
- Pathogenic organism production
- Pest breeding
- Odour generation
- Requirements for education

6. On-site Miscellaneous

- Institutional requirements
- Allowable population density and dwelling requirements
- Adaptability to social practices and living conditions
- Waste handling requirements

Each process is defined by up to three generic construction cost, O&M cost and land requirement curves based on hydraulic loading, organic loading and solids loading. The majority of the cost and land use data were taken from USEPA references. All costs were brought forward to a common base year of 1992 based on an Engineering New Record (ENR) index. Costs are then brought up to the first year of the proposed project by WAWTTAR based on the inflation rate data provided in the community profile tables.

Most of the cost curves are average costs in the United States for a wide variety of geographical and economic settings. These cost curves are then localized by WAWTTAR by adjusting based on component cost factors for the community of interest using data provided in the community profile tables. For construction costs, the relevant component cost categories are labor, earthwork, manufactured equipment, structures, concrete, steel and appurtenances. For O&M costs, the relevant categories are labour, chemicals, materials and energy.

Building Treatment Trains

As has been previously noted, it is a requirement that users of WAWTTAR have at the very least an acquaintance with water and wastewater treatment processes. At best, the user should be thoroughly familiar with conventional and non-conventional treatment processes. This familiarity should include process performance ability, equipment description, operation and maintenance requirements, human resource requirements, effective combinations of processes and environmental requirements. This knowledge is first applied to WAWTTAR in the selection of the sequence of processes which the user instructs WAWTTAR to consider.

This development of a series of processes to meet a particular standard, guideline and/or reuse goal is referred to as "building treatment trains". The WAWTTAR program will not automatically build treatment trains. The user must select processes and arrange them in a logical order in terms of the flow of the water, wastewater and/or solids. There are no default treatment trains in the database.

The development of a wide range of alternative treatment trains for consideration is at the heart of the WAWTTAR program. The user is able to prepare large numbers of different treatment trains by combining the various unit processes found in the WAWTTAR process database. The number and types of alternatives to be considered is a decision the user must make early in his or her planning process. The wider the variety and the greater the number of treatment train alternatives proposed, the greater the probability that a sustainable, feasible solution will be found.

The diagnostic ability of WAWTTAR identifies specific resources or conditions which do not support a particular process within a treatment train. This allows the user to address the weakness, if possible, and then re-examine the train for feasibility. This aspect of the program is as valuable as the program’s ability to identify those trains and processes that can feasibly be supported in a particular community.

Obtaining Results

After WAWTTAR has completed the calculations resulting from the combination of site-specific community information and the selected treatment trains, the program output is written into two output files. These files are the Feasible Solution File and the Infeasible Solution File. A display menu is used to view these files along with other output files.

Infeasible Solution File

A description of any treatment train that does not meet the criteria established by the user is sent to the Infeasible Solution File. The design or performance criteria not met will be listed for each process in the train responsible for making the train infeasible. Frequently, infeasible trains can yield more insight into the design or process problem than feasible trains, so the user is encouraged to examine, edit and recalculate the performance of infeasible trains. A viable train may be found to be infeasible due to the inclusion of a process which is incompatible with, for example, influent quality, and the train may be rendered feasible with a relatively minor alteration. This is one of the key aspects of use of WAWTTAR which relies intensively upon the level of expertise of the user.

Feasible Solution File

Detailed descriptions of feasible treatment trains are written to the Feasible Solution File. Breakdowns of capital costs, O&M costs, land requirements and land costs per process are provided in the output as are the total cost for the train, total per capita cost and total cost per dwelling. Adaptability indices which rate the adaptability of each train to upgrading, varying hydraulic loading and changes in influent quality are also reported. Solids production is detailed on a process by process basis. Final effluent quality for any constituents designated for tracking by the user is also reported.

The feasible treatment trains are ranked by the cost factor chosen by the user, and each feasible train is described with construction, O&M and total costs listed after the individual treatment train cost breakdowns. A list of the annualized costs, project costs, land requirements and social and environmental impacts for the optimal train completes the description of each feasible train.

Conclusion

WAWTTAR was developed as a predictive model to assist planners at the pre-feasibility project stage to select water and wastewater treatment systems appropriate to existing resources in particular locations around the globe. The purpose of WAWTTAR is to make available to decision-makers a user-friendly and widely accessible computer program and database with can be applied to urban and peri-urban settings and which can be used to assess traditional and alternative sanitation technologies and display tradeoffs by manipulating technical and socio-economic data which serve as principal inputs.

The key points regarding the application and use of WAWTTAR are contained in the following box:

WAWTTAR

Key Points to Remember

1. It is pre-feasibility software for selection of appropriate wastewater management processes.
2. It requires a wastewater engineer to maximize its application.
3. It provides an additional resource for an engineer to rely upon.
4. It also serves as a thorough reference for non-engineers.

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Treatment of Organic Waste from Industrial Facilities:

Application of the Anaerobic Technology for the Treatment of Domestic Wastewater in Jamaica

Julia Louise Brown
Scientific Officer, Integrated Wastewater, Management Project, Scientific Research Council,
Hope Gardens, PO Box 350, Kingston 6., Jamaica
Tel: (876) 927-1771 to 4 ext. 3102, Fax: (876) 977-2194, Email: icomppm@cwjamaica.com

ABSTRACT

The anaerobic technology is not foreign to Jamaica. This technology has been in use for over two decades as the conventional 'biogas plants' using animal manure. These plants are focused on generating energy for household purposes, however there have been advances in the technology. There is now the bio-septic tank for the on-site treatment of domestic wastewater. There is also the implementation of a demonstration anaerobic pond for the treatment of sugar wastewater. In developing countries like Jamaica, there are many competing demands on limited financial resources available for development. Sewage treatment, though important for public health, generally gets a lower level of recognition than for example a safe and reliable water supply.

The anaerobic technology has over the years generated a lot of interest from many different groups/institutions such as the government, the private sector, the farmers and the population at large mainly due to its energy producing potential. The anaerobic technology was promoted in Jamaica by the Government of Jamaica (GOJ) through the Scientific Research Council (SRC) and by the Government of Germany through the German Agency for Technical Co-operation (GTZ).

The anaerobic treatment of domestic sewage using the UASB process has previously been investigated under tropical conditions in countries such as Colombia, Brazil and India. The feasibility for such a process was explored in Jamaica since there are comparable climatic conditions.

The feasibility of the anaerobic treatment for sewage treatment was investigated by the operation of two 115 L UASB reactors in parallel. Reactor 1 was seeded with digested cow manure, while reactor 2 was not seeded (self-inoculation). Reactor 1 was used to determine the treatment efficiencies (BOD, COD and TSS) under the existing conditions of sludge activity, temperature, pH and wastewater concentration. Reactor 2 was used to show the possibility for self-inoculation to effect substantial removal efficiencies. Reactor 1 was subjected to stepwise reduction in HRT (11.5, 9.5, 7.5 and 4.6 hours) while reactor 2 did not show any initial stability in terms of removal efficiency and was operated at HRT of only 11.5 hours.

Reactor 1 was stabilised within 3-6 weeks of operation with COD, BOD and TSS removal of 70, 86 and 70 % respectively, resulting in an effluent quality of 60 – 150 mg COD/L and 12 – 30 mg BOD/L. Reactor 2 was achieving some stability after 12 weeks of operation with COD removal of 50 %, BOD of 65 % and TSS of 70 %.

Anaerobic treatment can become an attractive alternative for treatment in Jamaica. However, an anaerobic treatment is a pre-treatment process, post-treatment is required for the removal of pathogenic organisms, NH_4-N,PO_4^{3-} and the remaining suspended solids.

Keywords: Anaerobic technology, UASB process, domestic sewage, sewage treatment, post-treatment.

1.0 Introduction

1.1 Background

The anaerobic technology is not new to Jamaica. This technology has been in use for over two decades as the conventional biogas plants using animal manure. These plants are focused on generating energy for household purposes. There have however been advances in the technology to what is now called the bio-septic tank for the on-site treatment of domestic wastewater and since recently there was the implementation of a demonstration anaerobic pond for the treatment of sugar wastewater at one of the island’s sugar factories.

The anaerobic technology has over the years generated a lot of interest from many different groups/institutions such as the government, the private sector, the farmers and the population at large mainly due to its energy producing potentials. The anaerobic technology is now been promoted in Jamaica by the Government of Jamaica (GOJ) through the Scientific Research Council (SRC) and the Government of Germany (GOG) through the German Agency for Technical Co-operation (GTZ).

In developing countries like Jamaica, there are many competing demands on the limited financial resources available for development. Sewage treatment, although important for the public health, generally gets a lower level of recognition than for example a safe and reliable water supply system. The national average generation of sewage in Jamaica is 450,000 m^3/day, which is equivalent to approximately 50,000 to 60,000 kg BOD/day. Sewage is the largest source of pollution in Jamaica, although industrial water pollution takes a close second place (150,000 m^3/day). The effects on water pollution are to be found everywhere in Jamaica. The present on-site and most of the off-site systems of sewage disposal provide little treatment resulting in a direct disposal of the polluting load into surrounding ground and surface waters. The need for quick solutions has become a priority.

In view of the economical situation existing in Jamaica and the necessity for pollution control, wastewater treatment technologies should be cost effective and environmentally sound. It should combine a high treatment efficiency with plainness in construction and operation and the possibility for some form of efficient removal of pollutants.

As stated by Louwe Kooijmans and van Velsen (1986), sewage treatment in developing countries can be realized successfully only when the method of treatment has a bearing on the local conditions. This implies:

- Construction of the plant has to be simple with as less moving parts as possible and minimum of mechanization.
- The plant should be built with locally available materials.
- The investment costs have to be as low as possible with a low foreign currency component.
- The operation and maintenance of the plant has to be as simple as possible.
- **The energy requirement and the annual running costs have to be low.**
- In cases where land availability is restricted, low land requirement is an advantage.
- The preferred biological process has to meet the desired effluent quality standards.

Although the presently available conventional aerobic wastewater treatment systems may have very high removal efficiencies they suffer from severe drawbacks or disadvantages.

These are: -

- High operating cost for aeration
- High production of unstabilised sludge which has to be stabilised before disposal
- Lack of skilled manpower for operation
- High land requirement

There are also traditional pond systems, which are very effective in the treatment of domestic wastewater, but have the limitations of being too expensive if no cheap land is available.

The application of the anaerobic technology for the treatment of domestic wastewater was demonstrated under tropical conditions using the UASB process in Colombia (Lettinga, 1992; Schellinkhout et al., 1985, 1988), India (Draaijer et al., 1992), Brazil (Viera, 1988; Viera and Garcia, 1992) and Indonesia (Bogte et al., 1993; Lettinga et al., 1993) resulting in BOD removal of over 75 %. Jamaica has an average temperature of around 30 $_{o}$C and therefore provide a useful ground for such a study.

1.2 Objectives

The objective of the study was to assess the feasibility of the anaerobic technology for the treatment of domestic wastewater using the UASB system under Jamaican conditions in terms of:

- The removal of pollutants (BOD, COD, TSS);
- Optimising the design criteria for further extension of the UASB treatment systems in Jamaica by assessing the applicable hydraulic loading rate;
- Assessing the possibility for start-up without inoculum;
- Gaining hands-on experience in the operation and monitoring of anaerobic sewage treatment plants.

2.0 MATERIAL AND METHOD

The study conducted was divided into three phases or aspects. These are:

- Experimental set-up (system description)
- Process start-up
- Operation and Monitoring

2.1 EXPERIMENTAL SET-UP

2.1.1 Set-up (System Description – The Pilot Plants)

The pilot plant reactor system was installed at the Independence City, Portmore, St Catherine (Figure 2.1) and was fed with the sewage collected by the local aerobic treatment plant.

The pilot plant reactors have a total liquid volume of 115L (0.115 m^3) and are constructed of polypropylene (pp). They consist of a main pipe of 4.0 m tall (_ - 193 mm) to which an arm is attached, which serves as the sedimentation chamber and serves for the settling out of the solids and the collection and withdrawal of the effluent. It has a diameter of 153 mm, length of 953 mm and a volume of 17.5 L. The upper part of the reactor serves as the gas collection unit (5L) and at the joining of the sedimentation arm to the main pipe is the three-phase separator (gas-liquid-solids). Sampling ports are located at every 50 cm along the length of the reactors as 1.27 cm pp-ball valve connected to the main pipe with 1.27 cm pieces of pipes. The reactors are of the UASB type with one feed inlet, which is equivalent to one inlet per 0.03 m^2. The wastewater enters at the bottom and leaves at the top.

The sewage first enters the grit chamber where the sand and the grit are removed. From there it flows to a distribution tank where the wastewater is distributed to the aeration basin of the existing plant under gravity. The wastewater from the distribution tank was pumped to an equalization tank (225L plastic drum) from which the reactors were fed and the influent sampled. The wastewater was pumped to the drum and the reactors on a continuous basis and was only disturbed due to the occasional blockage of the hoses caused from the accumulated solids in the grit chamber and the distribution tank. The wastewater in the drum had a residence time of about 4h. The drum was however emptied and cleaned on a daily basis to prevent the accumulation of solids. It should be noted here that due to the accumulated solids in the grit chamber and the distribution tank as well as the rapid growth of algae in the hoses, very high COD and solids concentrations were sometimes occurring in the wastewater. This was dealt with by the thorough cleaning of the hoses on a weekly basis to prevent the accumulation, which would also, result in blockage and prevent the continuous operation of the system.

2.2 PROCESS START-UP

The two pilot plants (Reactor 1 and Reactor 2) were operated in parallel, reactor 1 (R) was seeded with digested cow manure and reactor 2 (R2) was not seeded (self-inoculation). R1 was used to determine the treatment efficiencies (BOD, COD, TSS) under the existing conditions of sludge activity, temperature, pH and wastewater concentration. R2 was used to show the possibility for self-inoculation to effect substantial removal efficiencies (BOD, COD, TSS).

For the non-seeded plant (R2) the following was done.

- The plant was filled with wastewater.
- The feeding was stopped for four week to assist in the development of the sludge bed through processes of sludge accumulation and sludge improvement.

- The feeding of the system was then re-started to continue the development of the sludge bed and to monitor the performance of the plant.

This process of feeding the system then allowing it to rest for a period of two weeks was based on the experience made in Kanpur, India (Draaijer et al., 1992) for the start-up of a UASB plant without inoculum.

R1 was loaded with 40 L of the digested cow manure (22.14 g TSS/L; 13.22 g VSS/L) as the inoculum and then allowed to stand for a day to acclimatize to the existing conditions within the plant, after which feeding was started. The sludge bed was then allowed to grow and become acclimatized to the wastewater until steady state conditions were achieved.

2.3 SYSTEM MONITORING AND OPERATION

2.3.1 Influent – Effluent

Both the influent from the equalization tank and the effluent from the sedimentation chamber of the pilot plant were sampled into a cooler initially using diaphragm pumps which pumps between 100-500mL/h. Due to the malfunctioning of some of the pumps (broken springs) the effluent was allowed to flow under gravity to the sampling containers in the coolers. These composite samples (24 hours collection time) were taken to the Waste Management Laboratory of the Scientific Research Council for analysis.

2.3.2. Sludge Sampling

The sludge was sampled by taking a proportional sample, that is, along the entire length of the reactor. This was done using a 1.27 cm PVC tube with a length of 4.5m containing a cord and a stopper running through the entire length. The tube was inserted into the reactor by removing a stopper from the gas chamber (see figure 2.3). When the tube was fully inserted and full of sample, the cord was tightened and the tube was now closed and removed from the reactor and the sample collected into a measuring cylinder.

2.3.3 Sampling and Analysis

The following analyses were performed for the monitoring of the pilot plant. The frequencies were chosen to get a wide appreciation of the behaviour of the system over the entire experimental period, as well as in response to the workload that could be handled for the study.

Table 3.1: Basic operating conditions of the reactor systems (Mean ±standard deviation and the Range)

Period (Days)	Temperature (° C)	pH	Surface Load (m/h)	HRT (hrs)[H]
2-43	28± 2 (26–30)	7.4 ± 0.5 (6.9–7.7)	0.35	11.5
43–80	27 ±2 (25–29)	7.6 ± 0.3 (6.8–8.3)	0.42	9.5
80–111	28 ± 2 (26–29)	7.5 ± 0.2 (7.3–7.7)	0.53	7.5
111–123	29	7.4	0.87	4.6

Parameters Frequency	
Influent - Effluent	
Temperature	Daily, momentaneous, on spot
pH	Daily, momentaneous, on spot
COD (total, settled, centrifuged)	Daily, momentaneous, on spot

BOD_5 TSS, VSS VFA, Alkalinity* NH_4-N, TKN **<u>GAS</u>** Production **<u>Sludge Bed</u>** MLSS, MLVSS Methanogenic Activity Settleability Stability Sludge Mass	Weekly, 24 hrs composite sample Weekly, 24 hrs composite sample Weekly, 24 hrs composite sample Weekly, 24 hrs composite sample Daily Every six weeks Every six week Every six week Every six week Every six week
** During the first four weeks, it was done on daily basis.*	

For the analysis on the influent and effluent the standard method were followed with the exception of the COD. The COD was analysed according to the Hach method (see below). The gas production was measured using a wet gas meter. The settleability (initial settling velocity and sludge volume Index) were determined using the Imhoff cone. Total suspended solids and volatile solids were determined according to the standard method. The anaerobic activity and sludge stability was measured in a batch experiment using molasses as substrate at 30 ° C. The volatile fatty acids and alkalinity were analysed titrimetrically.

COD

The COD was measured using a Hach System from Hach International situated in the United States of America. It consist of Hach COD-reactor DR/2000 spectrophotometer and vials containing COD reagents 0 – 15000mg/L, 0 – 1500mg/L and 0 – 150mg/L). This method was tested by the analytical laboratory of the Scientific Research Council (SRC) and is comparable to the standard method of measurement ($\pm$10 %).

3.0 RESULTS AND DISCUSSIONS

3.1 INTRODUCTION

Due to occasional periods of pump breakdowns, it was impossible to keep the plant in continuous operation over the whole experimental period. The clogging of the filter (even though cleaned daily) and the growth of algae in the hoses hampered the smooth operation of the plants. This showed major impact on the irregular pattern of the gas production.

3.2 START-UP OF THE UASB REACTORS

The operation of R1 was started at a HRT of 11.5 hours during days 2 – 43, 9.5 hours during days 43-80, 7.5 hours during days 80-111 and 4-6 hours during days 111-123. R2 was operated at only HRT of 11.5 hours because the removal efficiency (BOD, COD and TSS) did not indicate early stabilization to effect step-wise reduction in the HRT. The basic operating conditions of the plants are shown in table 3.1

3.3 SYSTEM MONITORING AND OPERATION

The results presented were obtained during a five month period of operation (end October 97– end March 98).

3.3.1 Influent - Effluent

3.3.1.1 Influent Characteristics

The sewage treated in the pilot plants was domestic in origin and originated from the independence City sewage collector which receive the wastewater of seven communities of approximately 130,500 inhabitants. According to the National Water Commission (NWC) the water consumption is approximately 250 L/cap/day and approximately 80 % is discharged. The wastewater is very septic in nature (COD / BOD ratio = 3.00 – 3.77), very high in suspended-COD (157 mg TSS/L, 125 mg VSS/L) and was very dilute (COD- 429 mg/L (see table 3.2). This was similar to the situation observed in Cali, Colombia (Lettinga, 1992). The most important characteristics of the sewage are presented in table 3.2, which present the average values as measured over the entire experimental period.

Table 3.2: The main characteristics of the Independence City sewage.

PARMETER		**ENTIRE PERIOD**			
		X	Stdev	Min	Max
CODtotal	(mg/L)	429	± 233	138	123
CODcentr.	(mg/L)	151	± 60	33	325
CODsettled	(mg/L)	194	± 76	58	408
BODtotal	(mg/L)	118	± 28	63	169
COD/BOD		365			
TSS	(mg/L)	157	± 129	10	667
VSS	(mg/L)	125	± 112	5	607
TKN	(mg/L)	31.1	± 5	2.7	38.1
NH4-N	(mg/L)	20.5	± 3.1	14.9	24.4
Temp	(^{o}C)	28	± 2	25	30

The averages and ranges calculated from selected sewage parameters for each HRT are shown in table 3.3

Table 3.3: Main influent characteristics at the different HRT (mean Standard and Deviation Ranges)

HR (Hours)	CODtotal (mg/L)	CODcentr. (mg/L)	CODsettled (mg/L)	BOD (mg/L)	TSS (mg/L)
11.5	336 ± 190 (138–842)	135 ± 61 (33–269)	172 ± 70 (75 – 393)	110 ± 30 (63-140)	115 ± 88 (10-402)
9.5	407 ± 167 (141-971)	166 ± 62 (60-320)	218 ± 81 (80-330)	108 ± 10 (90-121)	119 ± 90 (44-457)
7.5	554 ± 28 (181-1233)	152 ± 57 (58-339)	189 ± 78 (56-246)	168 ± 0.7 (168-169)	239 ± 158 (45-667)
4.6	504 ± 279 (188-785)	150 ± 49 (100-206)	202 ± 67 (133-304)	not determined	246 ± 157 (77-406)

3.3.3.1 Performance of Reactor 1

As shown in figure 3.5, from the beginning of the experiment, the performance of the plant in terms of COD – removal efficiency was fairly satisfactory (>50 %). The low removal efficiency (ECOD total) during the initial period of operation (HRT = 11.5 h) can be attributed to the absence of a sufficient quantity of proper bacterial sludge to carry out the digestion of the organic material. However, the low regions of ECOD total at HRT of 9.5 hours is mainly due to the sludge washout that occurred during that period (see figure 3.5). The treatment efficiencies based on centrifuged effluent samples relative to total influent samples, ECOD Max, represent the maximum possible efficiency of the system that can be achieved under the prevailing conditions. This ranges from 75 – 86% for the different HRT. These results obtained are comparable to the results obtained from studies under tropical conditions in Cali, Colombia (70 – 90 %) as shown by Lettinga (1992) and in Kanpur, India (>75 %) as shown by Draaijer et al. (1992).

With the stepwise reduction of the HRT and the subsequent increase in the volume and the activity of the sludge due to the growth of sufficient quantity of proper bacterial sludge, the overall removal efficiency increased. This increase in COD – removal could also be attributed to the fact that at the lower HRT there was an increase in the influent COD concentration. It was observed that at higher influent COD values there was an increase in the removal efficiency (ECOD total and ECOD Max). The occasional washout of sludge from the reactor and the growth of algae in the effluent hoses affected the overall ECOD total. Nevertheless, an ECOD total of 65 – 75 % was achieved.

BOD

The BOD was analysed on weekly composite samples and maintained a very high removal efficiency of 82 – 90 % (see figure 3.6). The BOD values in the effluent range from 9 – 30 mg/L, which is within the limits of the Jamaican standards of 30 mg/L.

TSS

Despite the high levels of solids in the influent, the removal of solids in the system was fairly satisfactory. This ranges between 58 – 82 % for different HRT. The initial low TSS (HRT = 11.5 h) in the system can be explained by the small amount of sludge that was present in the reactor, which reduces the likelihood of entrapping non-settleable solids in the system. However this was improved with time due to the increase in the sludge mass, which increased the entrapment of the non-settleable suspended solids. The occasional washout of sludge from the reactor and the growth of algae in the effluent hoses affected the TSS removal efficiency like the ECOD total.

3.3.3.2 Performance of Reactor 2

R2 was operated at only one HRT (11.5 h) and was operated with the aim of ‘self inoculation’ to effect efficient removal (COD, BOD and TSS) as well as to observe the possible time period required for start-up. The process of self-inoculation is of eminent practical importance, as adequate seed materials for start-up is not available in developing countries like Jamaica.

As can be seen in figure 3.9 the COD removal efficiency (ECOD Max and ECOD total) follows a very irregular pattern. During the first few months or period of operation not much happened with respect to ECOD total. This could be due to the fact that the incoming wastewater was very dilute and the reactor was therefore started at too high a HRT (11.5 h). This resulted in the inability of solids present in the wastewater (TSS – 144 mg/L) to settle in the reactor and was washed out in the effluent. This was confirmed in the ECOD Max (see figure 3.9) which was fairly satisfactory from the beginning with a removal efficiency greater than 50 % signifying the inability of the system to remove the soluble COD. As is evident from figure 3.9 with time the possibility for ‘self inoculation’ to effect substantial removal efficiencies in COD is feasible and could possible be faster if reactor is initially operated at a lower HRT (e.g. 24 h).

BOD

The BOD removal in the system was fairly satisfactory and ranges between 60 – 70 % with values in the effluent of 32-40 mg/L.

TSS

The TSS removal efficiency in R2 like the COD removal follows a very irregular pattern (see figure 3.10). The inability of solids to accumulate in the system was evident in the TSS removal. This can be explained by the lack of sludge in the reactor during the initial period of operation, which prevented the likelihood of entrapping non-settleable solids in the reactor. There was an overall removal efficiency of over 70 %. The initial (period 1) high removal of solids in the system resulted when there was little solids present in the influent (see table 3.3).

3.3.4 Gas Production

The gas yield in R1 was an average of 0.13 Nm3 CH4 /Kg COD removed. For R2 the gas collection was hampered by the problems encountered and thus was not included in the results.

3.3.5 Sludge Bed Characteristics (R1) and the effect of the reduction in HRT

The methanogenic activity of the sludge in R1 was determined every six weeks at the change of each HRT. Specific activity measurements at 30 °C on the sludge made over the entire experimental period reveal a gradual increase from 0.24 kg COD/kg VSS. day at HRT of 11.5 h to 0.4 kg COD/kg VSS.day at HRT of 7.5 h to 0.54 kg COD/kg VSS. day. However at HRT of 9.5 h there was a decrease to 0.1 kg COD/kg VSS. day, which is unexplainable.

The sludge load obtained in the reactor was 0.05 – 0.3mg COD/mg VSS.d and was low in comparison to that of activated sludge (0.5 – 1.0mg COD/mg VSS.d (see figure 3.11). This may be due to the low methanogenic activity or due to a low supply of organic matter and was confirmed by a plot of the maximum methanogenic activity and the value measured in the reactor (SLR) again the HRT as is shown in figure 3.11.

From figure 3.11 there was no identity of the measured maximum specific activity and that of the values measured in the reactor. All the maximum activity values exceeded that of the values measured in the reactor at all HRT, indicating that there was a substrate limitation within the reactor at all the HRT.

The settleability of the sludge as determined by the Sludge Volume Index (SVI) ranges from 15 – 30 mL/g for the different HRT indicating a good settleability for the sludge. This could be explained by the increase in superficial velocity with a decrease in HRT (see table 3.1).

The amount of sludge in the reactor decrease with a decrease in HRT (see table 3.4), which was due to the occasional sludge washout that, occurred in the system through sludge growth and subsequent sludge bed expansion.

Table 3.4: The sludge composition and sludge mass in R1 at the different HRT

HRT g TSS/L	Sludge Mass	Sludge Composition
11.5	22	0.60
9.5	24	0.66
7.5	17.5	0.58
4.6	16.3	0.68

The sludge stability was assessed from the methane production of the sludge samples at the different HRT. The methane production was followed for a period of three weeks. The sludge was stabilised with a production of 14-47mL CH_4/g VSS.

The sludge age or solids retention time within the system was between 33-75 days.

The excess sludge production in the system was estimated on the basis of the TSS removal efficiency and the volatile fraction of the influent suspended solids and the sludge present in the reactor respectively. Together with the TSS content of raw sewage, the excess sludge production can be estimated at approximately 63 kg TSS/1000 m^3 wastewater (10.15 kg TSS/kg COD).

CONCLUSION

4.1 Summary of Results

A study was conducted using two reactors, one seeded (R1) and the other unseeded (R2) to demonstrate the feasibility of the anaerobic treatment of domestic wastewater in Jamaica. A summary of the results is shown in table 4.1.

Table 4.1: Conclusions of results of pilot plants experiment in Portmore, Jamaica with domestic sewage.

1 For R1 start-up can be achieved at a HRT of approximately 5 hours within 3-6 weeks. While for R2, which was unseeded, start-up can be achieved at HRT of 11.5 hours (it was operated at only this HRT) within 15-20 weeks. However, it is possible that start-up can be done at a higher HRT if the initial phases are operated at a lower HRT (e.g. 24 hours) and then decreased.		
2a. Treatment efficiencies R1 (HRT 11.5 – 4.6 hours)		
	COD (total/total) COD (total/centrifuged) BOD (total/total) TSS	55 – 72 % (64 %) 74 – 86 % (80 %) 82 – 90 % (86 %) 58 – 82 % (70 %)
2b. Treatment efficiencies R2 (HRT 11.5 hours)		
	COD (total/total) COD (total/centrifuged) BOD (total/total) TSS	30 – 70 % (50 %) 52 – 72 % (62 %) 60 – 70 % (65 %) 60 – 80 % (70 %)
3. Gas production R1		0.13 Nm^3 CH_4/kg ^{COD} removed
4. TSS-conversion (R1) Appr. 27 % of the TSS leaves the reactor in the effluent Appr. 42 % of the TSS is found in the sludge Appr. 25 % of the TSS is converted to gas		
5. Sludge retention of the reactor and sludge age		
	Sludge retention (R1)	16.5 – 23.5 kg TSS/m^3 10.3 – 15.4 kg VSS/m^3
	Sludge retention (R2)	1.9 kg TSS/m^3 1.8 kg VSS/m^3
	Sludge age (R1)	33 – 75 days
6. Sludge bed characteristics (R1)		
	Ash content Spec. Meth. Act. Stability	35 – 45 % 0.1 – 0.54 kg COD/kg VSS.day 14 – 47 mL CH_4/g VSS

4.2 Overall Conclusions

1. Anaerobic treatment can become an attractive alternative for Jamaica because:

    - Under Jamaica's tropical conditions dilute sewage can be digested efficiently under both seeded and unseeded conditions as shown on pilot scale

    - In Jamaica where there is a general problem existing with high rate treatment system due mainly to financial reasons, anaerobic process indicates an economic advantage.

    - Significant low sludge production rate reduces the cost for sludge treatment/disposal. The sludge is also well stabilised.

2. In view of the satisfactory performance of the seeded system (R1), particularly in terms of its positive response to the imposed higher hydraulic loading rates, it can be concluded that the system is suited to accommodate a higher rate of start-up.
3. The unseeded plant (R2) initial phase of operation should be done at a lower HRT (24 hours) to allow some form of sludge built to take place so that start-up can be achieved at a higher rate and in a shorter period of time.
4. As anaerobic treatment is a pre-treatment process, post treatment is required for the removal of pathogenic organisms, NH4-N,PO43- and the remaining suspended solids.

5.0 RECOMMENDATIONS

5.1 Reactor 1

The study was conducted over a period of only five months, which was insufficient to thoroughly explore all the parameters or areas necessary to optimise the process for further design purposes. Therefore the plant should continue to be operated with better control of the influent (in terms of solids) with reduction in the HRT in an attempt to establish maximum point of operation for the system for design purposes.

5.2 Reactor 2

The plant should continue to be operated for at least another six months in order to establish stability in terms of COD and BOD removal and for it to be subjected to stepwise reduction in HRT so that the maximum potential of the system can be established. This would provide for more concrete conclusions to be made of the possibility for self-inoculation for the treatment of domestic wastewater in Jamaica.

6.0 REFERENCES

Draaaijer, H., Maas, J.A.W., Schaapman, J.E. & Khan, A. (1992). Performance of the 5 MLD USASB reactor for sewage treatment at Kanpur, India. *Water Science and Technology*, 25(7): 123 – 133.

Bogte, J.J., Brere, A.M., van Andel, J.G., & Lettinga, G. (1993). Anaerobic treatment of domestic wastewater in small scale UASB reactors. *Water Science and Technology,* 27 (9): 75 – 82.

Lettinga, G., de Man, van der Last, A.R.M., Wiegant, W., van Knippenberg, K., Frijns, J. & van Buuren, J.C.L. (1993). Anaerobic treatment of domestic sewage and wastewater. *Water Science and Technology,* 27 (9): 67 – 73.

Louwe Kooijmans, J. & van Velsen, E.M. (1986). Application of the UASB process for the treatment of domestic sewage under sub-tropical conditions, the Cali case. Anaerobic Treatment. A grown-up technology. Conference papers (Aquatech 1986), p423 – 436.

Schellinkhout, A., Jakma, F.F.G.M. & Forero, G.E. (1988). Sewage treatment: the anaerobic way is advancing in Colombia. Fifth International symposium on Anaerobic Digestion (Poster-papers. Tilche A and Rozzi A, Eds. Bolgna, Italy p767 –770.

Schellinkhout, A., Lettinga, G., van Velsen, L., Louwe Kooijmans, J. (1985). The application of the UASB-reactor for the direct treatment of domestic wastewater under tropical conditions. *Proceedings of the Seminar/Workshop on Anaerobic Treatment of Sewage.* Switzenbaum Ed. Amherst, USA, pp. 259 – 276.

Lettinga, G. (1992). Treatment of raw sewage under tropical conditions. Malina, J.F. and Pohland, F.G. *Design of Anaerobic Processes for the treatment of Industrial and Municipal Wastes.* Water Quality Management Libraries. Vol.7, USA. P 147 – 166.

Viera, S.M.M. (1988). Anaerobic treatment of domestic sewage in Brazil – Research results and full-scale experience. *Proceedings of the 5th International Symposium on Anaerobic Digestion.* Bologna, Italy. Hall ER, and Hobson PN, Eds. P185 – 196.

Viera, S.M.M. & Garcia Jr., A.D. (1992) Sewage treatment by UASB reactor. Operation results and recommendations for design and utilisation. *Water Science and Technology,* 18 (12): 109 – 121.

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GLOSSARY

Aerobic Anaerobic BOD COD E^{COD}Max E^{COD}total GOG GOJ GTZ HRT MLSS MLVSS NH_4-N Nm^3 CH_4 NWC R1 R2 SRC SVI TKN TSS UASB VSS	Presence of dissolved oxygen Absence of dissolved oxygen Biochemical oxygen demand, the amount of oxygen needed to biologically degrade the organic matter present in the wastewater Chemical oxygen demand Maximum removal efficiency based on the total Total removal efficiency based on total influent COD and the total effluent COD. Government of Germany Government of Jamaica Germany Agency for Technical Co-operation Hydraulic Retention Time, the time in which the wastewater is maintained within the system, measured by the volume of the system over the flow. Mixed Liquor Suspended Solids Mixed Liquor Volatile Suspended Solids Ammonium-Nitrogen, the usable form of nitrogen for the bacteria Amount of methane produced under standard conditions of temperature and pressure National Water Commission, the water governing body in Jamaica which is responsible for >20 of the sewage generated Reactor 1, the pilot plant reactor that was seeded with sludge Reactor 2, the pilot plant reactor that was not seeded with sludge Scientific Research Council Sludge Volume Index (mL/g), the volume occupied by 1g of sludge after settling of mixed liquor for 30 minutes Total Kjeldahl Nitrogen, NH_4-N + 0-N_2 Total Suspended Solids Upflow anaerobic Slidge Blanke/Bed, the most common type of anaerobic reactor for wastewater treatment Volatile Suspended Solids

Low Cost and Low Technology Alternatives for Wastewater Treatment

John A. McKee, M.Sc., CGWP, P.Eng.
Oliver, Mangione McCalla, 154 Colonmade Road South, Nepean, Ontario, Canada K2E 7J5
Tel: (613) 225-9940 ext. 241, Fax: (613) 225-7337, Email: omm@trow.com

Introduction

The objective of wastewater treatment is to remove, convert and/or reduce the toxic and pathological components of wastewater such as to effectively reduce the risk to human health and ecological impact associated with effluent release to the environment. The level of treatment required in a specific application is dependent upon the hydraulic and organic load of the wastewater source and the required quality of the effluent. The quality of effluent which can be tolerated varies from one application to another and is dependent upon the environment into which the effluent is released.

A wide variety of treatment technologies and methods of implementation have been developed to meet the various treatment requirements and constraints. These range in complexity from the simple pit privy or septic tank/leaching field system for small domestic applications to the technically more sophisticated packaged systems such as the Rotating Biological Contactor (RBC), Sequencing Batch Reactor (SBR) or Extended Aeration Plants (EA) designed for higher flows, wastewater strengths or more demanding discharge requirements. Each of these systems has a specific application or niche within the wastewater treatment field.

The focus of this presentation will be low cost/low technology methods for wastewater treatment. The focus will be on systems suitable for daily flows in the 5 to 50 m^3/day (and larger) range. A variety of applications will be considered including multiple family domestic, institutional (ie. schools), commercial (ie. retail, restaurant) and industrial.

By comparison with the technically sophisticated systems discussed above, low technology systems are simple in concept, design and operation. In most cases, the only operating component is a simple effluent pump. If required energy requirements can be met from solar power cell/battery combinations. In certain circumstances, systems can be setup to run entirely on gravity. Once established, ongoing operational and maintenance requirements are minimal. There is no requirement for ongoing balancing or chemical adjustment. High level training of operators is not required.

System Descriptions

A brief presentation of three low cost /low technology systems used in North America will be provided. These three systems are described as follows:

- Peat filter;
- Recirculating sand filter;
- Waterloo Biofilter.

The experience of the author is primarily with the peat filter systems which are discussed in detail. The latter two are presented because they meet the low cost/low technology criteria while providing a high level of effluent treatment. Data published by Ball (1995), Bruen and Piluk (1994), Roy and Dube (1994) will be used to describe the recirculating sand filter.

Various papers published by Dr. Craig Jowet (1994, 1995) can be used to describe the Waterloo Biofilter system.

A brief description of the conceptual design and operation of each system will be presented together with a description of the treatment mechanism. The degree of treatment provided in various applications as experienced by the author and/or reported in the literature will be provided. There is an inherent variability in wastewater strengths associated with the various sources. Parameters considered in this discussion will include Biochemical Oxygen Demand (BOD), total phosphorous (as P), Total Nitrogen (total kjeldahl+nitrite+nitrate as N), and the bacteriological parameters total and fecal coliform.

Peat Filter Systems

Peat filter systems for the treatment of domestic wastewater were originally developed at the University of Maine by Dr. J.L. Brooks et al (1984). Working together with Dr. Brooks, the firm Oliver, Mangione, McCalla successfully adapted and implemented the technology to serve a variety of uses including single and multiple family residential, elementary and high schools, commercial retail and restaurants. A detailed evaluation of the performance of these systems was undertaken for the Ministry of the Environment for the Province of Ontario (OMM 1997), the results of which will be summarized herein. In addition to the above, the literature provides references to the use of peat for the treatment of industrial effluent containing heavy metals and landfill leachate.

The design and operating principals of peat filters have been discussed in previous publications including Brooks et al (1984), McKee and Brooks (1994) and McKee and Connolly (1995). A schematic sketch of a typical peat filter treatment system is provided in figure 1. Primary treatment of the wastewater is provided by a conventional two chamber septic tank. The effluent then flows by gravity or alternatively is pumped to the peat filter system. The effluent is distributed over the area of the peat filter through a network of perforated distribution pipes. Dependent upon the setting, distribution can alternatively be accomplished through pressure distribution or drip irrigation systems.

Treatment is provided as the effluent percolates vertically downwards through the peat to the base of the system. The peat material acts as a host medium for micro-organisms which accomplish the effluent treatment in an aerobic environment. The literature reports the use of various types of peat from different sources with differing degrees of success. The peat used in the systems described herein is a sphagnum type peat with a Von Post decomposition rating of H-4, a pH of 3.5 to 4.5 and moisture content of 50 to 60 percent. This material is packaged and can be easily shipped in bulk.

Effluent from the base of the peat can be handled in a variety of ways. For the systems constructed in Ontario, the effluent percolates through the base to the groundwater table. Depending upon the setting and regulatory requirements, systems can also be constructed with under drain systems for discharge to remote leach fields, trenches or surface water.

A summary of the peat filter systems for which monitoring programs have been undertaken is provided in table 1. The systems serve a variety of uses with varying waste water strengths. Design flows range from 2 to 36 m^3/day and organic loading of 34 to in excess of 500mg/L BOD.

A detailed monitoring program of the above systems was completed and summarized by OMM (1997). The program involved the collection of samples from the septic tank and base of the peat filter at monthly or quarterly intervals for periods of from two to three years each. The results of analysis are summarized below.

		Years Operate	Design Flow m^3/day	BOD mg/L		Phosphorous mg/L-P		Nitrogen Mg/L-N	
				range	avg	range	avg	range	avg
Schools	Elementary	8	15	48 - 143	92	2 - 9	6.1	40 - 80	65
		6	10	28-341	132	1 - 10	4.8	52 - 101	82
		5	10	0-76	34	3 - 8	6	45 - 74	57
		4	20	17-96	55	0 - 10	5	35 - 75	63
		5	9	15-176	73	1 - 14	7.8	63 - 165	109
	Secondary	5	36	90-563	185	2 - 16	7.7	44 - 150	92
Domestic	Single Fam	5	2		331	23 - 48	34	129 - 198	157
	Multiple Fam	5	9		142		8.7	49 - 80	52
		5	7	110-195	141	2 - 12	6.8	8 - 30	40
Restaurant		5	18	285-717	502	8 - 24	15	67 - 183	100
Shopping Center		5	25	44-84	59	1 - 7	4	18 - 40	27
		5	25	125-676	401	1 - 21	8.3	30 - 130	64

Table 1: Summary of Peat Filter Systems and Influent Wastewater Characteristics

Available data indicates peat filters provide very high levels of treatment for the bacteriological indicator parameters, total and fecal coliform. Reductions effectively exceed 99 percent. Total and fecal coliform counts in almost all cases met the criteria for swimming water quality (total

1,000 per 100 ml, fecal 100 per 100ml) and in many cases exceeded the drinking water criteria for total coliform of 5 per 100ml.

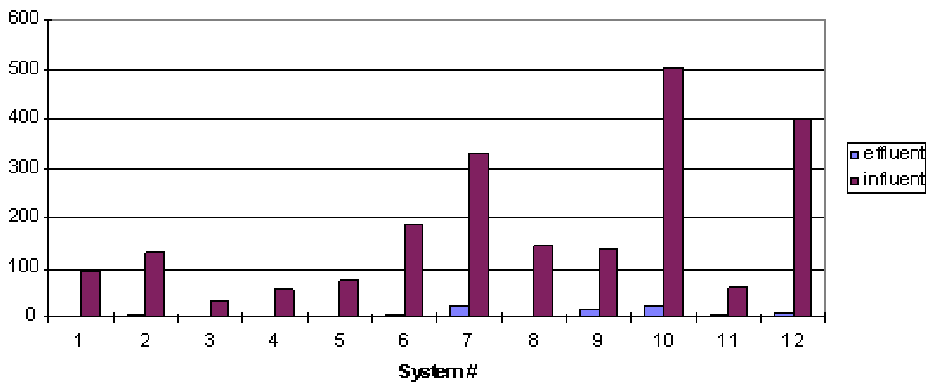


Figure 2: BOD Treatment - Peat Filters

Treatment of the organic component of wastewater is measured by the reduction in Biochemical Oxygen Demand (BOD). The results for the twelve systems are summarized in figure 1 above. Influent sewage strength varied with the nature of the source from relatively weak at less than 100 mg/l, to strong with average strengths in excess of 500mg/L.

In all cases, the peat filters provided excellent treatment for the removal of BOD. Average reductions exceeded 90 percent. With the exception of the very high strength sources, the effluent BOD concentrations were less than 10mg/L. BOD source strength is an important design consideration. At loading rates of less than 5,000 mg/m^2/day, effluent concentrations were generally less than 10mg/L. At loading rates in excess of this amount, an organic clogging mat can develop. Pretreatment should be considered for higher strength wastewaters.

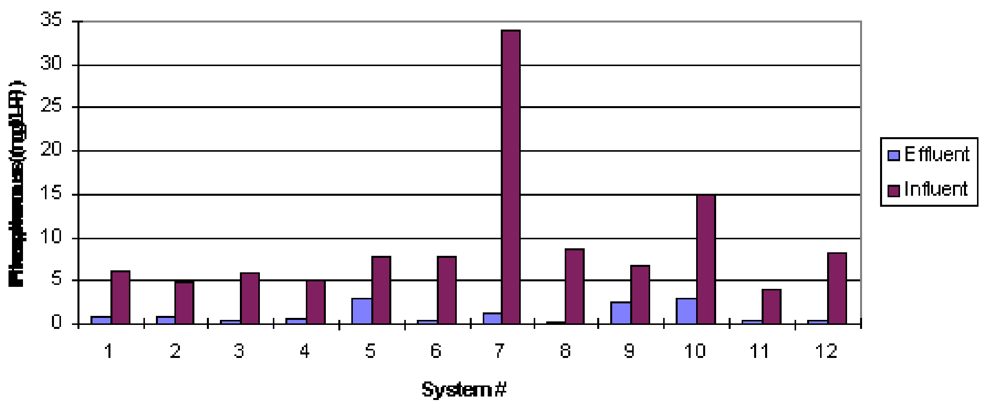


Figure 3: Phosphorous Treatment - Peat Filter

The removal of phosphorous by peat filters is very good, with most systems exceeding a ninety percent removal rate. Effluent phosphorous concentrations were generally less than 0.8mg/L-P in most systems. Higher source strengths generally produced higher effluent strengths. The high strength restaurant wastewater, with an influent phosphorous concentration of 15mg/L-P had an effluent concentration of 2.8mg/L-P.

The phosphorous treatment provided by the systems studied by OMM (1997) is higher than that reported by other authors (Brooks et al 1984). This is attributed to the perceived difference in treatment mechanisms. The process for treatment of organic compounds, nitrogen and bacteriological parameters is believed to be facilitated by biodegradation/bioaccumulation undertaken by micro-organisms. Phosphorous reduction is considered to occur by adsorption.

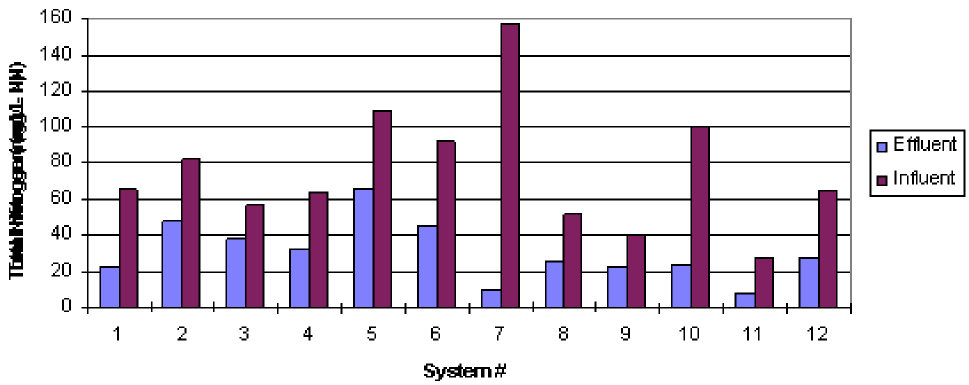


Figure 4: Nitrogen Treatment - Peat Filter

The assessment of nitrogen treatment involved the collection and analysis of influent and effluent samples for Total Kjeldahl Nitrogen, Ammonia, Nitrite and Nitrate (measured as N). The sum of all nitrogen species was considered at each stage in the treatment process as summarized in figure 4 above.

Treatment within the peat filter occurs under aerobic conditions (Brooks et al 1984). Influent nitrogen was measured primarily in the form of ammonia and organic nitrogen. Essentially complete nitrification occurred within the peat filter with effluent nitrogen measured primarily in the form of nitrate. The overall reduction in nitrogen species is dependent upon nitrogen loading. Average reductions varied from 35 to 70 %. A fifty percent reduction in total nitrogen species was obtained in systems with a total nitrogen loading of 1.4 grams/m^2/day. Design of the peat filter should consider both the influent wastewater strength and requirements for the point of discharge.

The author has had experience with the design construction and operation of a total of fifteen peat filter systems. Costs for construction of the complete system have generally ranged from 7 to 12 $CAN per litre for the complete system. Costs are comparable or only slightly higher than conventional septic or sand filter systems. Costs are lower than the more sophisticated packaged systems described at the beginning of the paper by a factor of 2 to 3 or more. The real advantage of the peat filter system is the low operational and maintenance requirements. Operating cost is restricted to the effluent pump which typically runs no more than 60 to 90 minutes per day. Once established, the systems operate with minimal supervision. Maintenance is generally restricted to the periodic cleaning of the septic tank.

Recirculating Sand Filters

Sand filters and more recently, recirculating sand filters (RSF) are in common use in unsewered areas of the USA and are now being implemented in various areas of Canada. Figure 5 provides a schematic layout of a typical recirculating sand filter. Septic tank effluent flows by gravity to the recirculation tank where it is pumped to the sand filter. Treatment in the sand filter occurs under aerobic conditions providing effective treatment for the removal of organic material (BOD) and micro biological contaminants. Sand filters are effective for the nitrification of ammonia and organic nitrogen to nitrate. Recirculating sand filters were developed to provide for improved treatment for nitrogen. Nitrified sand filter effluent is redirected and mixed with the raw wastewater where, denitrification occurs under the anaerobic conditions of the septic tank. It is reported that trickling filters have been added to the septic tanks to further increase nitrogen removal efficiencies (Ball 1995).

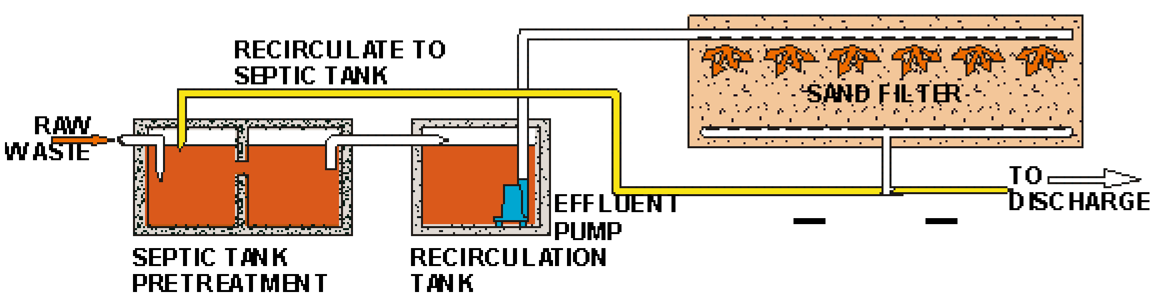


Figure 5: Schematic Layout - Recirculating Sand Filter

The sand filter consists of a minimum 0.6 metres of sand or gravel. Varying gradations of sand have been reported. Piluk and Peters (1994) report an effective grain size of 1 mm and uniformity coefficient of < 2.5. Ball (1995) reports a sand of effective grain size 2 mm to be the most effective for nitrogen removal. The reported rate of loading to the sand filter is variable, ranging from a low of 2 cm/day (Roy and Dube 1994) to as much as 55 cm/day (Piluk and Peters 1994).

The reported treatment efficiencies provided by RSF systems is very good. With respect to bacteriological components, reductions of two orders of magnitude in fecal coliform were reported by Bruen and Piluk (1994). Removal effectiveness is in part related to the thickness of the sand filter. Dependent upon the setting and regulatory requirement, disinfection of effluent would be required prior to discharge to the surface water environment. The removal of organic contaminants as reflected by BOD concentrations is good with RSF systems. Removal efficiencies in excess of 90 % were reported by Piluk and Peters (1994), Roy and Dube (1994).

In recent years, attention has been focused on the design enhancement of RSF systems to provide optimum nitrogen removal. Nitrogen removal rates of 30 to 50% have been consistently demonstrated in a variety of climates (Ball 1995). Bruen and Piluk (1994) report 66% nitrogen reductions. The focus now is to increase this reduction by the addition of trickling filter systems on the recirculation side of the septic tank/pump chamber (Ball 1995).

The cost for construction of RSF systems was reported by Bruen and Piluk (1994) for domestic applications. An approximate cost of $5,850 US was reported for a home of two adults, four children. Using an estimated 2,000 L/day flow, the equivalent system cost is therefore on the order of $3 US/Litre. Similar to the peat systems. RSF systems require little to no maintenance once commissioned. Operating costs are limited to the energy required to operate the effluent pump and periodic maintenance of the septic tank.

Waterloo Biofilter

The Waterloo Biofilter™ (WBF) is a proprietary system developed by Dr. Craig Jowett (1994, 1995) of the University of Waterloo, Canada and marketed by Waterloo Biofilter Systems Inc. of Guelph Ontario. Jowet (1995) reports the use of these systems to treat a variety of wastewater applications ranging from single family residential and municipal wastewater to landfill leachate.

Similar to the Peat and RSF systems, wastewater is treated in the WBF system as it passes through the media, in this case an absorbent plastic media or foam with a high pore to solid ratio. Wastewater is sprayed or sprinkled onto the surface of the biofilter media where it is absorbed. As with the peat and RSF systems, treatment is accomplished under aerobic conditions by micro-organisms hosted within the medium. Treated effluent is directed to the subsurface via leaching beds or shallow disposal trenches or depending upon the regulatory setting directed to surface water environment.

Treatment in the WBF systems if very good. Jowet (1995) reports removal rates for fecal coliform of 99%. As with the RSF system, disinfection of wastewater prior to surface water discharge would be required. The removal and treatment for organic contaminants as reflected by the BOD is good. Reductions on the order of 90 % or better were reported for a number of single family domestic and a municipal application. The WBF system consistently reduced the BOD of a landfill leachate by 79%.

Treatment for nitrogen compounds is similar for the peat, RSF and WBF systems. Nitrification of the effluent occurs under aerobic conditions within the filter medium. Ammonia removal in the wastewater is reported by Jowett (1995) to be 80 to 90 percent. Total nitrogen removal for these systems is reported in the range of 29 to 37%. Modifications to the system have increased the nitrogen removal efficiency to 65%. The modifications involve the addition of a denitrification module, consisting of a tank of sawdust which receives the WBF effluent prior to discharge. Denitrification occurs within this system under anaerobic conditions with the sawdust providing a source of carbon for the denitrifying bacteria.

Direct information on costs for construction of the WBF system can be obtained from the manufacturer. As with the peat and RSF systems, operating costs are minimal associated with the cost for operating effluent pump and blower systems and periodic maintenance and pumping of the septic tank.

Summary and Conclusions

A wide variety of technologies have been developed to treat wastewater. Each of these technologies has a specific niche within the market with applicability dependent upon such considerations as wastewater volume and delivery patterns, wastewater strength and required effluent quality. The required quality of effluent will depend upon the sensitivity of the environment into which the effluent is discharged and applicable regulatory requirements.

The focus of this presentation has been low cost/low technology alternatives for wastewater treatment. Three systems have been discussed: Peat filters, Recirculating Sand Filters (RSF) and the Waterloo Biofilter (WBF). The three systems provide very high levels of treatment for the organic compounds as measured by BOD and nitrification of ammonia and organic nitrogen. All systems provide excellent treatment for bacteria with removal efficiencies exceeding 99%. Peat filter effluent consistently meets swimming water criteria for fecal coliform. Depending upon the setting, disinfection of RSF and WBF effluent could still be required.

Treatment for nutrients in the form of nitrogen and phosphorous varies with the systems. The peat filters provide good treatment with effluent concentrations less than 1 mg/L in most applications. Phosphorous removal modules are being developed and are available for the RSF and WBF systems.

Nitrogen removal efficiencies of 40 to 70% can be achieved with the peat filter. Similar rates have also been reported with the RSF system. The use of a denitrification module in conjunction with the WBF system brings nitrogen removal efficiencies into the same range as the other two systems.

The initial capital costs for these systems are generally low, ranging from $5 to $15 CAN/Litre. Operating costs for these systems is low, consisting primarily of the energy cost associated with operating a small effluent pump. With the exception of the periodic cleaning of the septic tank which provides primary treatment for the three systems, maintenance requirements for these systems is low with little involvement required once the system is in operation and properly balanced.

References

Ball, H.L., 1995. Nitrogen Reductions in an On Site Trickling Filter/Upflow Filter System. 8th Northwest On-Site Wastewater Treatment Short Course and Equipment Exhibition, University of Washington.

Brooks, J.L., Rock, C.A., and Struchtemeyr, R.A., 1984. The Use of Peat for On-Site Waste Water Treatment: 2 Field Studies. Journal of Environmental Quality, Volume 13, No. 4, Pg. 524.

Bruen, M.G. and Piluk, 1994. Performance and Costs of On-Site Recirculating Sand Filters. In Proceedings, 7th International Symposium on Individual and Small Community Wastewater Systems, ASAE, Atlanta.

Jowett, E.C. and McMaster, M.L. Absorbent Aerobic Biofiltration for On-Site Wastewater Treatment - Laboratory and Winter Field Results. In Proceedings, 7th International Symposium on Individual and Small Community Wastewater Systems, ASAE, Atlanta.

Jowett, E.C. 1995. Field Performance of the Waterloo Biofilter with Different Wastewaters. 8th Northwest On-Site Wastewater Treatment Short Course and Equipment Exhibition, University of Washington.

McKee, J.A. and Connolly, M. 1995. An Update on the Use of Peat Filters for On-Site Wastewater Treatment. 8th Northwest On-Site Wastewater Treatment Short Course and Equipment Exhibition, University of Washington.

McKee, J.A. and Brooks, J.L., 1994. Experience with Peat Filters for On-Site Wastewater Treatment in Ontario. Conference on Wastewater Nutrient Removal Technologies and On-Site Management Districts. Waterloo Centre for Groundwater Research, University of Waterloo, Canada.

Oliver, Mangione, McCalla & Associates, 1997. Summary Report, On-Site Wastewater Treatment, Thirteen Peat Filter Systems. Prepared for Ontario Ministry of the Environment.

Piluk, R.J. and Peters, E.C., 1994. Small Recirculating Sand Filters for Individual Homes. In Proceedings, 7th International Symposium on Individual and Small Community Wastewater Systems, ASAE, Atlanta.

Roy, C. and Dube, J.P. 1994. A Recirculating Gravel Filter for Cold Climates. In Proceedings, 7th International Symposium on Individual and Small Community Wastewater Systems, ASAE, Atlanta.

The National Small Flows Clearinghouse and Lessons Learned from the National Onsite Demonstration Project

David A. Pask
National Small Flows Clearing House, PO Box 6064, West Virginia State University,
Morgantown WV 26506-6064, USA
Tel: (304) 293 4191 ext. 5516, Fax: (304) 293 3161, Email: dpask@wvu.edu

Abstract

This paper describes the National Small Flows Clearinghouse as a resource for individuals and small communities of the Caribbean seeking information and support for problems of sewage treatment and disposal or pollution control. The National Onsite Demonstration Project is also described with a discussion on some of the results of the monitoring program. The importance of management of small systems is discussed together with the rationale for selection of an appropriate system for a given circumstance. A method for the estimation of the hydraulic capacity of a site is given with a description of techniques for measuring necessary parameters.

The Environmental Services and Training Division (ESTD) of West Virginia University

The National Small Flows Clearinghouse (NSFC) and its sister organizations, the National Drinking Water Clearinghouse (NDWC) and the National Environmental Training Center for Small Communities (NETCSC) are national non-profit information services provided by the University of West Virginia and are located on campus in Morgantown, West Virginia. The U.S. Environmental Protection Agency (EPA) funds NSFC and NETCSC, while the U.S. Department of Agriculture funds NDWC. All three organizations were founded to assist small communities affected by the need to comply with ever more strict environmental legislation.

The clearinghouses are staffed by engineers, technical and administrative assistants, writers and editors totaling approximately 65 persons. A number of national experts in various fields are also available for referral when the need arises. During business hours trained staff are available to receive telephone calls for advice on almost any subject related to water, wastewater and environmental training. Queries may be received by telephone (toll-free within U.S.A.), by Fax or regular mail. Most calls can be dealt with immediately, but referrals, and items requiring some research may take a little longer. The Clearinghouses each produce two quarterly newsletters relating to technical and administrative matters. Internet Web sites are maintained and include electronic versions of the publications. Access will shortly be available to the very extensive databases of technical and administrative abstracts. A very important service is the operation of a product distribution service covering books, manuals, pamphlets and videotapes published by the Clearinghouses, EPA and other government and independent organizations. Some items are free with a small charge for shipping and handling, other items may include the cost of copying and binding.

The Clearinghouses send representatives to many of the national and state conferences and workshops, usually operating a staffed display in the exhibit area. Members of staff are frequently asked to speak at these and other conferences.

The clearinghouses may be contacted –

by mail:	The National Small Flows Clearinghouse (or NDWC or NETCSC) West Virginia University P.O. Box 6064 Morgantown, WV 26506 – 6064
by phone:	1 800 624 8301 (within US) 1 304 293 3161
by Fax:	1 304 293 3161
by Internet:	http://www.estd.wvu.edu

National On-site Demonstration Project, Phase 1

This project is drawing to a close. Six communities in five states participated in a program intended to demonstrate proven alternative on-site technologies in sensitive areas where lack of way to knowledge and/or regulation inhibited current acceptance. These technologies ranged from modified standard septic tank/soil absorption through various forms of secondary treatment for nutrient reduction to wetlands and drip irrigation. Monitoring was a requirement and included some sophisticated sampling by lysimeter.

Results in general showed that the innovative technologies are indeed an improvement over existing systems in protecting public health, groundwater and the environment but also showed that more sophisticated treatment leads to the need for more sophisticated maintenance and management. This can no longer be left to the average homeowner and his untrained pumper!

National On-site Demonstration Project, Phase 2

The experiences of Phase 1, have steered the advisory committee towards asking for an emphasis on projects that will emphasize management aspects. All five participants will include management and maintenance in the objectives of their demonstration. One participant will concentrate all the effort into all the preparatory surveys and organization required to put in place on on-site wastewater management district. Others will also include some innovative systems not already in use in the area.

The NSFC National Survey of On-site Systems in the United States

This recently completed survey is a first attempt at assessing the status of the industry and of the problems we will be facing in the immediate future. Tailored for maximum response, a remarkable 45% return was produced from 3,500 questionnaires. The report has now been published and is available from the Clearinghouse. A paper was presented at the ASAE meeting in Orlando by Tricia Angoli in March of this year.

No specific questions were asked about management issues but a general trend can be inferred from "Other Comments" added by respondents. Two papers at the above conference specifically addressed the need for management; several other speakers mentioned the need when describing alternate systems. I met no-one at many informal meetings at this and other conferences and workshops that did not acknowledge that some form of management of maintenance will be required for all systems throughout the country, especially for systems using advanced treatment.

Misconceptions as to the Use of Advanced Treatment Systems

While advanced treatment systems do have their uses, there are examples where the public, installers and some professionals are advocating advanced treatment as the universal panacea for all the ailments of on-site systems. I must add a few words of caution. Many malfunctions of onsite systems are related to inadequate hydraulic conductivity of the subsoil. ***Advanced treatment has no effect upon the hydraulic capacity of a building lot, Darcy's Law still applies!***

Advanced treatment should not be used unless there is a specific reason for its requirement. A Decision Diagram may best illustrate this point. The following example is almost universal in application.

Issues in Establishing Wastewater Management

The following is a partial list of the many issues that may need to be resolved in setting up a Wastewater Management District or similar entity. Many of the decisions are both political and social, but must be addressed.

A WHY MANAGE?

1) Protect health and environment for all.
   Does this need explanation?

2) Minimize “Failure” (malfunction).
   Failure needs defining.

3) Ensure compliance with local and state regulations.
   Regulations may also require update.

4) All treatment needs maintenance.
From the simplest to the most sophisticated

5) Many homeowners do not maintain.
A non-budgeted item?

B HOW (alternate choices)?

1) Management by homeowner with inspection.
Simplest, least invasive

2) Management by contractor with (less) inspection.
Must be scheduled

3) Management by PSD by contract.
Must be scheduled

4) Direct management by PSD.
PSD employee and equipment

Note: For B(1) & (2) homeowner pays for each service
For (3) & (4) homeowner pays monthly service fee

C POLICY ISSUES FOR B (3) & (4)

1) Access required for homeowner property.
A turf issue

2) Who brings system to standard at start?
Can be an unbudgeted financial investment for the homeowner unless amortized into monthly charges

3) Who pays for repairs/maintenance in continuum?
Can be direct charge to individual homeowner or shared equally among all subscribers as a monthly charge

4) How do you deal with low income homes?
May be difficult unless universally amortized

5) How do you enforce?
If central water service, this could be cut?

D PROCEDURAL ISSUES

1) Commitment of representatives is a prerequisite.
   Community must be sold on the idea usually means that a good PR campaign is needed

2) New Ordinances may be required.
   These may cover enablement, regulation, enforcement, permits, licence to practice, design (prescriptive or performance based), easements and rights of way

3) A plebiscite may be required.
   Depends upon local ordinances

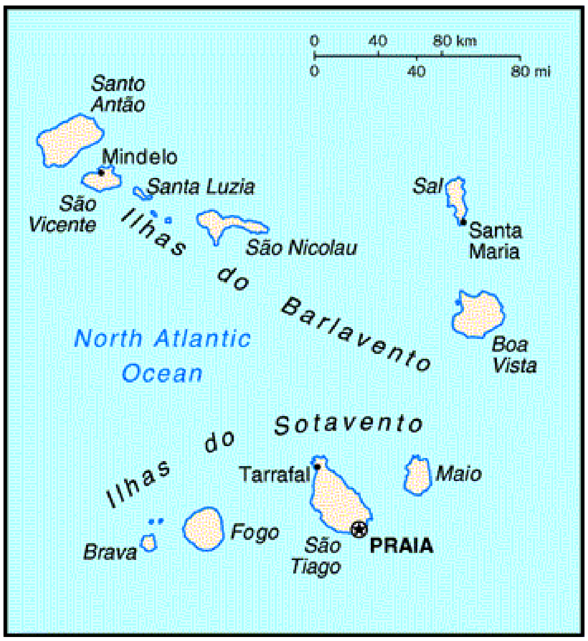
Many homeowners would prefer a fully sewered service, despite the very high capital cost. It may be easier to convince a community to accept managed.

Wastewater Management In Cabo Verde

Mr Antunio De Cassia Sousa Barbosa
Director, Directorate General of Marine Affairs, PO Box 7, S, Vicente, Cabo Verde
Tel: (238) 324-342, Fax: (238) 324-343, Email: dgmp@milton.cvtelecom.cv

Introduction

Cape Verde is an island State lying in the Atlantic Ocean some 300 miles from the African continent and belonging to sub-Saharan region. This archipelago is a group of ten islands and several islets. The total land area is 4.033 km^2 and it has a coastline of 1017 Km. By geographical coordinates its extremes points are 17º 12´ N, 14º 48´ N, 22º 40´ W and 25º 22´W.



The islands are of volcanic origin and seem to be on the ocean crust between 120 to 140 million years old. Cape Verde's natural environment is deeply marked by insularity, predominance of volcanic landscape with high altitudes and steep slopes, and a differentiated microclimate and vegetation characteristics, which are a result of altitude variations and the position in relation to the trade winds. Droughts are well known in Cape Verde and have been the most typical element in this sahelean country. Matter of fact, this characteristic is inscribed in almost all of the country's cultural manifestations.

With exception of three most eastern islands – Maio, Boavista and Sal - the country is almost deprived of continental shelf. Actually, considering depth up to 200 meters, the overall continental shelf area is approximately 4.000 km^2.

Cape Verde has a 200-mile exclusive economic zone with an approximate area of 750,000 m^2 and is a country where development opportunities are limited due to low availability of drinking water, its small surface area and geographical dispersion, and little availability of natural resources. The strong demographic pressure on arable land (more than 400 inhabitants per square kilometre on arable land), the limited natural resources and low technological development have been factors of internal and external migrations. In effect, only 10% of the country's surface is arable, that is about 4.000 acres, and agriculture production covers for only 10 to 20% of the basic food needs.

The climate is tropical, mild and arid. The average annual temperature is 24ºC, stable because of the regulatory capacity of the ocean. The average surface water temperature is 23ºC, with a minimum of 21ºC and a maximum of 27ºC. There are two seasons in Cape Verde: the dry season from November to July when the trade winds blows, and the rainy season from August to October. The average rainfall per annum is a little more than 100 mm. This rain is erratic and randomly dispersed, therefore once a while the rain is heavy.

The population according to 1990 census was 341.491 inhabitants and today it estimated to be quasi - 400,000 people. Of the ten islands, all but one is uninhabited and the population distribution is uneven. For instance, Santiago, the biggest island has over 200.000 people, which represents more than 50% of population. On the other hand, Boavista, the third largest, has less than 4.000 people. This unbalanced distribution of population causes very high investment per capita as far as basic infrastructures are concerned. See population table annex 2. It might be worthwhile mentioning that Cape Verde has a very big Diaspora, comprising more than 700.000 people. Most of this group resides in United States and in Portugal.

In general the cape-verdean economy is characterized by a structural imbalance between national production, on one side, and consumption needs and capital building on the other. This economy is very dependent on imports, which is at the bases of the strong structural imbalances. In the same manner, the economy depends greatly on the outside world in order to satisfy the needs in terms of consumption and investments.

Cape Verde’s great economic dependence, illustrated by the dependence of the investment budget of 80/90 percent on foreign aid, is one of the main aspects of a reality which reflects the almost total absence of natural resources. The annual GNP per capita is estimated at US $803.00 but for 30% of the poorer population this amount lowers down to US$100.00. The sector distribution of the GNP shows the importance of the growing tertiary sector that constitutes 60% of the GNP. The agriculture and animal raising (livestock) sector since 1989 contributed only 6 to 10% percent of the GNP.

Administratively, Cape Verde is divided into 17 Municipalities with limited empowerment and greatly controlled by the central government. This fact stems from political disputes among the municipalities that do not belong to the same political party as the Government. With exception of Santiago (6), Santo Antão (3) and Fogo (2) every island is a Municipality in itself.

Environment in Cape Verde

The Constitution of Cape Verde dedicates to Environmental Protection issues. This Constitution of 1992, article 70, chapter II, part 2, determines that the State, the departments and the environmental protection agencies, have the responsibility of promoting the preservation and rational utilization of natural resources.

Environmental issues have been gaining some attention lately and mid eighties may be considered as reference point. The public awareness is low and only recently that some environmental education has started taking place in primary school.

With regard to marine living resources the biomass of cape-verdean waters is estimated to be in excess of 100.000 ton, two-third of which is associated with the islands of large continental shelf, namely, Sal, Boavista and Maio. Of this total, 35.000 tons represents demersals species and 65.000 tons pelagic ones. Additionally, Cape Verde is located on route of migrations of tuna fish; even tough several species are sedentary. In some coastal areas sea turtles have nests whereby they do the breeding. Green and rose lobsters are abundant.

The flora is composed of 240 aboriginal *taxa*, being 84 of these found exclusively in this country. There are a few endangered species that can be found in some islands. Presently about 45 aboriginal *taxa* are extinct due to deforestation. The terrestrial fauna is mainly composed of birds, reptiles and arthropods. Out of the 36 bird species that reproduces in Cape Verde, 17 (47,2%) are in danger of extinction. Seven of 28 reptile *taxa* in Cape Verde are also in danger of extinction. The entomological aspect of the cape-verdean fauna, one can account for 470 coleopteran species, being 155 found exclusively in this region. About 301 (64%) of this species are in danger of extinction and, it is presumed that 70 species are extinct.

The environmental legislation is incomplete and recent. In 1993 the basic law of the Environment was enacted – Law 86/IV/93. Several disperse pieces of legislation is into force but does not cover all aspect of environment protection. It seems that the lawmakers are aware of this handicap and some proposals are now being drafted to fill the gaps that still are in place. Exception is made relative to Law 79/III/90, which defines the marine protected areas. However, this law still requires regulation.

Water Resources and Sanitation

As stated above, water is scarce and in fact it is the biggest obstacle to development. Since early seventies the source of water started to be desalinization. The first island to accommodate such plant was S. Vicente. And since then three more islands are now served with desalinated water, Santiago, Sal and Boavista. The total production of desalinated water in 1997 was 1,681,000 m^3.

The ground water is depleting by the year and its sustainability can not be guaranteed. Indeed in 1984 the Water Code was enacted whereby the State nationalized all water resources as means to control its use and fair distribution to all.

On the other hand, with exception of desalination, the other sources of water are precipitation that occurs during the months of August and September, water tables and springs. The average annual precipitation varies with the topography and altitude of the islands. Therefore, the mountainous islands of Santo Antão, Santiago, Fogo and Brava have the highest average precipitation. Water supplied by rainfall is disturbed as follows: 67% is lost by evaporation, 20% is lost by runoff and 13% replenishes the ground water table. There are about 124 million m^3/year of ground water and only a fraction, estimated to be around 65 million m^3/year, can be technically explored. This withdrawal is lowering this value to 44 million m^3/year during the dry years (1970-1990).

If the water is scarce, one can conclude that the production the residual water is low. Regrettably the concept of sanitation versus the public health is not very well formulated in the policies.

Cape Verde has two main cities, Praia and Mindelo, the former is the capital with a population of 90.000 people, while the latter has a population of 70.000 people. Additionally it has several secondary urban centers, with population varying from few thousands to 25.000 people.

The country faces a situation of complete absence or great need of basic sanitation infrastructures considered indispensable for the quality of the lives of the people. These needs, besides conditioning the normal development of the sectors of the social and economic life, have serious implications in the public health.

With regard to sanitation, the country's global coverage is of 25%, thus distributed: sewage system (8%) bore sewers (5%), dry latrines (1%), others 11%. The current rate of coverage of the sewage network in the city of Praia is 9% and in Mindelo 65%. None of the secondary urban centers have sewage network, bore sewers are the only existing sanitation system in these centers. Living conditions are very critical, only 20% of the homes have a bathroom with sanitation facilities.

In Praia, in 1997 less than ten percent of the population benefited from the sewer system, however the system is under expansion. It is expected by the end of 1999 to increase that figure to 20% percent and potentially this figure can go up to 27%. At present the major obstacle to be connected to the sewer network seems to be the cost, which varies from US $150 to $300 depending on the value of the house. This shortcoming causes an under utilization of the sewer network whose capacity is designed for an intake of 647 m^3/hr.

Wastewater Treatment Plant of Praia

The treatment plant is of primary type and located in Palmarejo, a valley situated some 15 meters below the residential area, and it comprises the following:

An intake structure followed by two screening devices. The first one is made of vertical bars with a shape of an arc with spacing of 50 mm and the second one with spacing of 20 mm. The first screening device is manually cleaned and the other is mechanically cleaned. These devices remove big solid materials that are found in the sewage. Additionally the system has an aired sand removal device of square cross section with a capacity of 36,5 m^3. A movable skimmer is fitted in a settling tank of rectangular shape, which in its forward motion skims the scum and other fat components of the sewage, and on the opposite direction skims the sludge in the bottom of settling tank.

At the end of the system a holding tank is used for disinfecting of the effluent prior to discharge in cases of emergencies, i.e. cases of cholera, diarrhea, etc. The disenfection is carried out by a solution sodium hypochlorite. An underwater emissary located some 700 meters from the station discharge the effluent to the sea through a diffuser.

The treatment of solid part is taken care by a sludge digester of anaerobic type working at atmospheric temperature. This digester is of conic shape and is followed by a pressing filter, which dehydrates the treated sludge after mixing it with a solution of polyelectrolyte.

The station in Praia was designed with the following parameters:

Parameters	**Units**	**1995**	**2005**
Inhabitants covered	Inhabitants	24794	121135
Inhabitants connected	Inhabitants	15214	101124
Specific load	l/cap/day	85	120
Average daily flow	m3/day	647	8494
Average flow	m3/hour	27	354
BOD 5			
Specific load	g/cap/day	30	40
Average concentration	mg/l	705	475
Total carrying capacity	kg/day	456	4044
DRY MAT TER			
Specific load	g/cap/day	30	60
Average concentration	mg/l	705	710
Total carrying capacity	kg/day	456	6066

The last available record, in March 1998, indicated an average inflow of 14 m3/hr with a maximum of 24 m^3/hr.

Routine operation of the plant consists of the following:

Pumping of sludge from settling tank to the digester every morning for 10 to 15 minutes. The sludge in the digester remains there for two to three months. Afterwards it is removed and dehydrated by the pressing filter and disposed of by burying.

Pumping compressed air every morning and afternoon for 3 hours provides air for the sand removal device.

The station came into operation in September 1997 and is run by staff of six persons.

The wastewater are controlled analytically only with respect to physical parameters – temperature, pH and conductivity – and suspended solids. A new laboratory facility is to be built in the near future. It is expected that when this lab come into operation it would be possible to control the wastewater in its chemical and bacteriological aspects.

The complete treatment cycle lasts less than 24 hours and it varies according to the load, i.e. the smaller the load the bigger is the retention time.

The plant in Praia was conceived to accommodate an expansion and to be converted to a secondary treatment plant.

Wastewater Treatment Plant of Mindelo

In the city of Mindelo, S. Vicente 65% of population is connected to the sewer network. The amount of wastewater the station can handle is about 2,200m^3/day, but at present it receives 1,700 m^3/day.

The wastewater treatment plant is of secondary type. Before the effluent reaches the station it undergoes a primary treatment at four different pumping station located at several points in the city. This treatment consists of screening in a mesh filter. Screening devices are used to remove coarse solids, such plastic, metals, rags, paper, and the like from the wastewater. The primary purpose of screens is to prevent clogging of valves, nozzles, channels and other appurtenances.

For example, the screening device at Caisim (one of pumping station) is manually cleaned twice a week. The solid waste removed from bars is today thrown just outside the pumping station near the sea bank, so that the sea may dispose of it at tidal changes. Obviously this practice is a bad solution since this sludge, besides posing a public health threat, it is also harmful to the environment to say the least.

In case of malfunction of the pumping stations raw sewage is directed straight into the sea.

The effluent of primary discharge treatment contains unsettled solids, organic matter, and pathogens, i.e. organisms which causes diseases, which must be removed before the water is discharged. The primary treatment is therefore followed by a biological treatment step. The biological treatment units at Ribeira de Vinha consist of a pond system of three kinds: anaerobic, facultative, and aerobic also called maturation pond.

The active agents in biological treatment are microorganisms of which some by nature are present in the wastewater. To this group belong amongst other, bacteria, protozoa and algae, of which bacteria are the most important organisms.

The treatment step has to be constructed to favor microorganisms in the effluent, since they are a source of organic carbon. If the effluent from the biological treatment step is to be used for irrigation the amount of organic carbon has to be reduced or the roots of the crops will be suffocated since the oxygen in the water is used for consumption of carbon. It also important to reduce the amount of pathogens, otherwise these may transmit diseases to the people working in the field and to consumers of the crops.

To achieve the above mention quality of water/effluent, the treatment processes in ponds are the same as the purification processes of water in nature. This is done by leading the wastewater into ponds where microorganisms purify the wastewater. The water is detained until satisfactory treatment is reached. Complete cycle lasts for 21 days. Depending on the main biological activity that is taking place in the pond, they are called:

- Anaerobic ponds – dissolved oxygen is absent which is accomplished by increasing the pond depth, wastewater is anaerobic when it enter the treatment plant,
- Facultative ponds – at the bottom of the pond dissolved oxygen is absent thus creating anaerobic conditions in the bottom sludge, in the upper water layers of the pond air is allowed to mix the water creating an aerobic zone, also the algae produce oxygen when creating new cell algae,
- Maturation ponds – dissolved oxygen is present at all depths, this is made possible by making the pond very shallow and designing the surrounding areas beneficial for air mixing into the water, and as said above algae produce oxygen when creating new cell algae.

Wastewater treatment in pond system is a simple method of treating wastewater, since it does not require complicated mechanical devices and need very little maintenance compared with other types of biological wastewater treatment. It is suitable to use pond systems for treatment both municipal and certain industrial wastewater, though this category is scarce or non-existent at present.

Anaerobic pond

The main treatment process in an anaerobic pond is anaerobic degradation and mineralization of organic matter by bacteria producing methane, carbon dioxide and hydrogen sulfate.

The anaerobic pond reduces the organic load to a level, which is suitable for further treatment with facultative and later aerobic ponds. The main advantage with anaerobic treatment of heavily organically polluted water is that the production of biological sludge is low in anaerobic ponds compared with the production of biological sludge in aerobic ponds.

Complex organic matter	+	Facultative and anaerobic bacteria	⇒	Organic acids Aldehydes Alcohol Carbon dioxide Hydrogen	+	Methane forming bacteria	⇒	Methane Carbon dioxide Small amounts of other gases

Basic Anaerobic Reactions - Facultative Ponds

In facultative ponds the most complete treatment results are gained as far as single ponds are concerned. In ponds systems which includes both aerobic and anaerobic ponds, a facultative pond is necessary in between them to prevent anaerobic conditions in aerobic ponds. The basic treatment steps in a facultative pond are:

- Sludge separation by sedimentation,
- Anaerobic degradation and mineralization of sludge by bacteria, producing methane, carbon dioxide and hydrogen sulfate,
- Aerobic degradation of organic matter by microorganism, mainly bacteria,
- Biological growth of algae producing oxygen needed for aerobic biological degradation. The algae will then either be degraded by microorganisms or sediment as sludge,

The treatment processes that take place in facultative ponds, are of aerobic, anaerobic and facultative nature. The cooperation between these biological processes is complex, but may be described as follows. Figure 1 illustrates the main biological activities in a facultative pond.

In the aerobic zone aerobic bacteria and algae live in symbiosis as in an aerobic pond, i.e. the algae produce oxygen which the aerobic bacteria need to degrade organic matter, the bacteria in turn release carbon dioxide which the algae utilize together with sunlight to create new algae-cells.

When the algae die they will settle, together with other settled solids present in the water, to form bottom sludge. Anaerobic bacteria decompose the sludge since no dissolved oxygen is present at the bottom of the pond. The anaerobic decomposition yields inorganic nutrients and odorous compounds, e.g. hydrogen sulfate and organic acids. The odorous compounds will be oxidized in the aerobic zone of the pound thus preventing their emission to the atmosphere.

In the facultative intermediate zone facultative bacteria are decomposing organic matter. Facultative bacteria are bacteria that adapt to the amount of dissolved oxygen in their surroundings. When dissolved oxygen is present facultative bacteria will work as aerobic, otherwise they work as anaerobic bacteria.

Maturation Pond (Aerobic Ponds)

Aerobic ponds contain algae and bacteria in suspension. The bacteria break down the organic matter in suspension and produce carbon dioxide. The products of the bacteria degradation, especially carbon dioxide, and solar energy are then utilized by algae to create new alga-cells while releasing oxygen to solution, which is then used by bacteria. Bacteria and algae live in symbiosis in the aerobic pond, figure 2. Natural air mixing also provides oxygen, but to maintain aerobic conditions at all depths dissolved oxygen has to be added by photosynthetic activities.

Design Parameters

The wastewater treatment plant at Ribeira de Vinha consists of seven ponds. See Annex 1. Two anaerobic ponds running in parallel; one facultative, three maturation ponds which may be run separately, in series or in parallel; and one pond at the end of the biological treatment to store treated water before it is transported to the water reservoirs. The site is prepared for the addition of one anaerobic, one facultative, and one maturation pond.

Table 1. Specifications of the Ponds

PONDS	DEPTH [m]	AREA [m2]	VOLUME [m3]
A, B, C	2.5	1 000	2 500
1, 2, 3, 4	1.5	5 590	9 600
5	1.0	11 220	12 000
6	1.0	8 170	8 800
7	1.5	2 420	3 750

The area given in Table 1 is the area of the pond. Since the pond has sloping sides the volumes is larger than the area multiplied by depth of the pond.

Operation of the Plant Since Construction to Date

When the plant was constructed, the first phase was designed for a daily maximum inflow of 2250 m^3/day, but since COD/reduction of 80% in the facultative pond is desirable, the plant is only to cope with 1900m^3/day. However, in 1992 the amount of wastewater collected did not exceed 400 m^3/day, the volume of the ponds was far too large. This resulted in longer detention time than wanted, and that together with large pond area resulted in great evaporation. By its turn, due to large evaporation the salinity in each pond increased which disturbed the biological processes and made the treated water less suitable for irrigation.

In order to attempt to find a solution to the problems found several corrective actions were taken since then. At present some 1700 m^3/day reaches the plant, and the ponds were set up to be working in parallel and subdividing them also reduced its capacity.

The sewage network has been working normally and the maintenance staff has been able to overcome the daily problem they find. Daily cleaning is carried out at the pumping station, and weekly at the site. Physical control is done on weekly base in order to assess the quality of wastewater at inflow so preventive measures can be taken to avoid further damage of the network as a whole.

On the other hand, some difficulties are found, namely shortage of personnel to be on stand by on daily basis to attend the demands that occurs, low inventory of spare parts, lack of trained labor, poor behavior of customers, and high cost of service provided (connection to the network)

Laboratory Facilities

A new lab was recently built and it is fitted with equipment to control chemical, physical, and bacteriological parameters of wastewater, soil and products.

The plant operates with a staff of 33 personnel, and at present is managed by the Municipal Authorities of S. Vicente.

Treated effluent is then pumped to six holding water reservoirs located some 3 km from the treatment site where is supposed to be used for reforestation program and irrigation in agricultural projects. In this regard these projects are now simply on stand-by due to lack of understanding between the municipal authority and the central Government.

Septic Tank

In the secondary urban centers where there is no sewage network, the majority of houses use septic tanks as means of sanitation.

The system consists of two tanks working in series - a receiving tank and an absorbent tank. The first one is made of concrete structure, connected via a siphon to the second one which is made of loosen stone.

The principle behind the functioning of this system is that the sewage upon entrance of receiving tank undergoes an anaerobic biological treatment and the liquid phase of it moves on to the absorbent compartment for infiltration to the ground. Special trucks remove sludge that accumulates in the receiving tank roughly every four years.

Anaerobic conditions in the receiving tank must be created and maintained. The second tank is aerobic and this condition is achieved by ventilating the tank using a gooseneck pipe open to the surrounding atmosphere preferably located at the highest point of the house.

Precautions should be taken to avoid the disruption of the process, namely, keeping the receiving compartment sealed from air leakage, and avoiding the dumping of soap water directly into it since this kind of wastewater might have some ill effect on the living organisms in that compartment.

Regrettably the operation of septic tanks poses several problems to the users. First of all, the designing of the system does not follow strict technical recommendations; often the receiving tank ends up working, as a holding tank for sewage, in this situation cleaning becomes necessary more frequently. Secondly, the location of absorbent tank is located close to fresh water cistern posing a serious threat to public health in case of contamination by pathogenic and other organisms. This situation arises when there is low availability of surrounding area and in most cases as consequence of ignorance and lack of enforcement of the rules and regulations.

Lately, some houses, especially those constructed on the slopes are conceiving systems whereby the wastewater from showers and laundry - called soap water - is segregated from other source of domestic water and channeled to a filtering unit for re-use in irrigation of local gardens. The system works by using gravel, sand, porous stones and foam as filtering elements. The water flowing from those above-mentioned sources is left to settle in a tank where fats can float and then be removed. When it has reached a certain level it is siphoned to the filtering element. The application of this system is being encouraged since it contributes to lowering the consumption of fresh water and therefore making it available to more people and generating higher savings to them besides creating some green areas.

As a matter of fact, in Sal Island the hotel resorts located in Santa Maria – about five – have facilities whereby domestic wastewater can be treated locally and later re-use in irrigation of gardens.

Industries and Industrial Wastewater

The country is practically deprived of industries. Exception is made to a brewing industry (in Praia) a small soap factory (in S. Vicente) and several very small units such fish processing in tins, filling of soft drinks, and some textile factories. In fact this is a good reflection of Cape Verde dimension, smallness.

Therefore when we talk of industrial wastewater very little can be said. The brewing industry located in Praia, some 150 meters from shoreline produces on average 60,000 hl of beer per annum. Being a major consumer of water, it is inevitable that the brewing industry is also a major effluent producer. Regrettably, the effluent produced in this plant is discharged directly into sea without any form of treatment. The plant has its own installation to produce fresh water and it generates more than 25 m^3/day of wastewater.

Since the brewing effluent is essentially rich in organic matters, this discharge into sea tends to deplete the dissolved oxygen present in the nearby water endangering so the marine life that exists there. Worst of all no prior analysis is carried out to assess the real impact of this discharge. The emissary is located in a closed bay where the port activity is very intense and one may say that that area is a sacrificed area.

Due to the increasing environmental awareness of the society, the management is looking into changing his attitude toward this existing practice. The possibility would be either to connect to main municipal sewer network or to recycle/treat the water for irrigation purposes. At present, the biggest concern regarding the effluent discharge has to do odor problems. This obnoxious odor is being dealt with by placing a mechanical filter on the stream of discharge to retain some malt that otherwise would find its way into sea and further the fermentation process. However, at present the problem still persists.

The soap factory located on S. Vicente Island is a small unit producing 1,620 tons of soap bars per year. The daily consumption of water is about 15 m^3, of which only 2 to 3 m^3 are wastewater. This residual waste is channeled to septic tank of about 40-m^3 capacity. No previous treatment is done prior to dumping. Concerns of contamination of ground were never taken into account. Fortunately, there exists no wells in the vicinity of the septic tanks, and as a matter of fact this Island is not furnished by ground water at all.

Sludge and other solid material are removed from septic tanks every two to three years by special truck.

Desalinization plants in S. Vicente, Santiago, Boavista and Sal discharge their brine directly into sea. This brine has a temperature of 50ºC and the salinity is of 60 mg/l.

Finally, huge amounts of superficial water from precipitation find their way into the sea through storm drains and in form of floods. However, this situation arises only when it rains, which is rare.

Conclusion

It stems from what is said above that the management practice of wastewater in Cape Verde is poor, very old fashion and it needs reviewing to be coherent with new demands of an environmental mind society.

A weak point for most environmental projects and programs is that they involve many government agencies with overlapping responsibilities. Sorting out this complicated web is very difficult, as it requires strong political commitment.

There is an urgent need to regulate this sector and to provide means to the central and local authorities to enforce and implement relevant legislation. This activity may be regarded as a challenge to everyone involved in catering for a sound environment since the cumulative effects of poor environmental management might cause some irreversible damage of our scarce resources.

Household Systems for Wastewater Treatment:

Household Systems for Wastewater Treatment

Goen E Ho and Kuruvilla Mathew
Remote Area Developments Group, Institute for Environmental Science, Murdoch University, Murdoch, Western Australia 6150

Associate Professor Goen Ho
Tel: (61-8) 9360-2167, Fax: (61-8) 9310-4997, Email: ho@essun1.murdoch.edu.au

Dr Kuruvilla Mathew
Tel: (61-8) 9360-2896, Fax: (61-8) 9310-4997, Email: mathew@essun1.murdoch.edu.au

Introduction

Isolated dwellings present their own problems of sewage disposal. The septic tank has conventionally been used to treat the sewage. It usually consists of one or two tanks for settling of solids with the overflow disposed via subsurface soil percolation. Depending on soil permeability a soak well is used in very permeable soil, whereas a trench is used where the soil is less permeable allowing for more infiltration area. Settled solids in the tank(s) undergo some anaerobic decomposition, but have to be emptied on a regular basis. Properly designed a septic tank may perform satisfactorily in unobtrusively conveying wastewater away from a dwelling. It can, however, pose health hazards in rocky or tight clay soils resulting in ponding of untreated sewage. More generally septic tanks contaminate groundwater with human pathogens, nutrients (nitrogen and phosphorus) and other pollutants disposed with domestic wastewater. The problems are accentuated where groundwater is close to the surface, or withdrawn for water supply for the isolated dwelling.

There are now a variety of options for wastewater treatment, disposal and reuse for isolated dwellings. Such systems can produce an effluent quality equal to or better than a conventional treatment plant. They may also be more cost effective than reticulated sewerage in rural and semi-rural areas besides isolated dwellings of remote areas, because extensive piping and pumping is avoided. There are also questions from the point of view of a local community particularly in developing countries besides the affordability of the chosen system for them, such as control over technologies that have the potential to influence the dynamics, form and autonomy of the community into which they are introduced. In addition there are now growing environmental and social pressures to consider reusing wastes and to begin introducing systems which are sustainable in the long term.

This section will discus the criteria to be considered in general in the process of selection of a particular technology for isolated dwellings and then describe a few technologies which are approved to be used in Australia to illustrate technologies that can be applied in other parts of the world. Use of local materials, modified design to suit local conditions and preference of a community should be taken into account when determining what is best for a particular case.

Criteria for Selection

During the selection process each option must be considered in terms of its ability to satisfy the following criteria. But in addition the extent of treatment necessary, the soil type or the site requirements and personal or community attitudes and preference should also be considered.

Reuse of Resources

Wastewater is often considered a source of public health problems to be disposed of and not as a resource. The choice of disposal and treatment system is usually governed by the disposal strategy. Reasons for reuse and options of reuse are well documented (Odendaal, 1992, Mathew & Ho, 1993). It is possible to use the treated wastewater and the sludge if proper treatment procedure is adopted while at the same time satisfying the guidelines for reuse (NHMRC, 1987; ANZECC, 1992).

Protect the Environment

Protection of public health is of the reason for treatment of sewage. Protection of the environment should also be considered. The conventional system of on-site disposal of wastewater is the septic tank and soil absorption system. The effluent from septic tank after soil treatment does not usually meet the criteria for maintenance of groundwater quality and hence needs further treatment (UWRAA/AWRC, 1992). Nutrient removal may become necessary in many situations where nutrients can cause pollution either directly by, for example, nitrate in the treated wastewater or through euthrophication of the receiving water.

Simplicity of Operation

A system sophisticated in its technology and control may tend to be complicated in operation. Frequent servicing and regular checking may become inevitable in operating an on-site treatment plant. While aiming for the best performance possible a system with minimum operational requirements and relatively easy and simple to maintain should be preferred.

Minimum Use of Chemicals

Chemicals have been used for phosphorus removal and disinfection. Biological phosphorus removal is to be preferred to chemical removal process. Disinfection by ultraviolet radiation should be considered in place of chlorination. Sub-surface micro-irrigation, for example, may not demand disinfection to the level it is necessary at present.

Other general aspects such as installation cost, maintenance expenses, aesthetic considerations, durability of the equipment and low energy consumption should also be considered in the selection of a system.

Systems Designed for Low Water Usage

Domestic sewage generally consists of wastes produced from the toilet, kitchen sink, bath and shower, wash basin and laundry. Toilet waste, generally referred to as black water, makes up to 25-30% of the total flow, while the other wastes comprise 70-75% of the flow is collectively referred to as grey water. The design of low water use systems attempts to reduce the amount of water, and black water may, for example, be reduced significantly producing only sludge. The black water contains the major portion of biochemical oxygen demand (BOD), suspended solids (SS), bacteria and nutrients. So if the black water is treated separately then treatment of grey water alone becomes easier and less complicated. The potential of pollutants being transported by the water in the black water is simultaneously significantly reduced, because water is generally the conveying medium for the pollutants.

V.I.P. Toilet

The Ventilated Improved Pit (VIP) toilet is a product of the Centre for Appropriate Technology (CAT), Alice Springs, Australia. Even though this is a pit toilet, its special construction ensures minimum odour and fly problems. It is possible for a family of five people to use the same unit for 10 years (Walker, 1985). In Australia this has been found to be suitable for camping places in national parks, main roads department highway rest sites, and remote communities.

Composting Toilet

Composting systems do not require any water connection, periodical pumping out, chemical dosing or on-going maintenance. It converts the waste with the nutrients in it into garden compost. It can be installed for single dwellings or community ablutions irrespective of the soil type of the area and should not create any environmental pollution. Three composting toilets approved by the Health Department of Western Australia are described below.

Clivus Multrum

The Clivus Multrum consists of a sloping, fibreglass compost tank which has been divided into an upper section for the treatment of fresh wastes and a lower section for the treatment of mature compost. The toilet seat is placed on the top of the tank. A vent pipe fitted with a fan to force the flow of air to the outside of the toilet is connected to the tank to keep the room odour free. There is a liquid drain which removes the excess liquid to keep the waste dry enough for composting. There are two inspection doors to provide access to both chambers. This can have multiple toilets and urinals with a capacity for up to 40 - 120 people. The pile should be inspected weekly to ensure adequate moisture levels and to add a bulking agent if necessary. It is suggested to level the pile quarterly and remove the compost from the lower chambers annually (Clivus Multrum, 1990). Vent-screens and pest strips may be used for pest control with a possibility of using a biodegradable pesticide in extreme circumstances.

Rota-Loo

Rota-Loo is designed for use by 6 - 8 people and hence is small and compact. It consists of four separate composting chambers in a circular container. Two of the chambers can be used simultaneously providing the opportunity of having two toilets using one housing unit. An air vent with a fan is connected to the main chamber to make sure continuous air flow is maintained. There is a heating element at the bottom of the chamber which keeps the temperature suitable for composting irrespective of the outside temperature. When one chamber is full the container is rotated thus providing the opportunity for maturing the compost. It is suggested to remove the compost annually and adjust its use to ensure enough time for composting (Rota-Loo, 1991).

Dowmus

The toilet seat of the Dowmus system is connected to a circular composting chamber of about 4.3 m3 which is of a sufficient volume for a family of five. It has a ventilation pipe with a fan to exhaust air from the bottom of the tank providing air flow through the compost. The compost can be extracted using an auger provided at the top of the tank towards one side. The Dowmus is partially filled with active compost at the time of installation and inoculated with beneficial soil organisms in particular tiger and red composting worms (Dowmus, 1993). There is no heating element and the system is not intended to operate above 35^0C, to protect the worms. The process depends more on soil organisms and worms rather than on the thermophilic microorganisms for composting. It can also take other household organic matters provided they are cut into small pieces. A family of five people can use this system for a few years without having to remove the compost.

Vermi-processing Toilet

BERI (Bhawalkar Earthworm Research Institute) vermi-processing toilet (BVT) has been field tested for 8 years in India and found to be a novel low water-use toilet for safe processing of human excreta without odour and fly problem. The toilet pan is directly connected to a tank of 1m x 1m x 1m which has a removable cover slab with ventilation holes. This can serve a family for about three years. BVT is started off by putting 5 kg of vermicastings in the pit (Bhawalkar and Bhawalkar, 1991). The operation of the toilet employing the pit is very simple and hygienic as the human excreta will be completely converted to vermi castings - a resource much needed for soil.

Aerobic Treatment Units

The common practice is to treat black and grey water together. Even when the black water is treated separately the grey water has to be treated by a system which satisfies the selection criteria described above. A number of such systems now available are listed in Table 1.

TABLE 1: Approved Household Aerobic Treatment Units in various States in Australia

	NSW	SA	VIC	QLD	TAS	NT	WA
Envirocycle	•	•	•	•	•		•
Supertreat	•	•					
Biocycle	•	•	•	•			•
Clearwater	•	•	•	•			•
Biomax K	•						
Biotreat	•						
Garden Master	•						
Model D10	•						
Parco Beaver	•		•				
Aerotor			•	Pending			
Biorotor			•	•			
Turbojet			•	•			
Aquarius							•
Ecomax							•
Envirotech				•			

NSW = New South Wales; SA = South Australia; VIC = Victoria; QLD = Queensland; TAS = Tasmania, NT = Northern Territory; WA = Western Australia.

These systems have a pre-treatment module similar to a septic tank which is for primary sedimentation and anaerobic decomposition. The recommended volume of 3 days storage for a septic tank (HCV, 1979) is followed by most of the systems. Domestic on-site systems receive wastewater usually as slug flows rather than as a constant flow. So the volume of the septic tank should be large enough to prevent the displacement of settled solids to the next chamber.

The most significant unit is the aerobic treatment chamber where the biological treatment process takes place to provide water quality to the secondary effluent standard. This is due to the effective contact between the incoming waste and bacteria in the aeration tank. Due to the slug flow in the small treatment units it is possible that the inflow may not achieve sufficient contact with treatment bacteria. So most of the systems operate with bacteria growing on fixed media which provide a longer contact time and less chance of bacteria washout, thus providing greater opportunity for removal of organic materials from the liquid. In a trickling filter or biofilter especially with new types of filter media with high availability of oxygen high removal rate is achieved within a shorter time. On the other hand in activated sludge system to achieve satisfactory level of treatment the wastewater has to be kept in the tank for several hours. Both processes are applied in different aerobic treatment units.

A secondary settling tank removes the suspended matter producing effluent with a secondary effluent water quality. The wastewater at this stage will normally have over a hundred thousand coliform bacteria per 100 ml which should be reduced to 10 per 100 ml. Most aerobic treatment units use chorination for disinfection.

The sludge produced in the secondary sedimentation tank is recycled to the septic tank for further treatment and storage. Desludging of the tank is required regularly, either small amounts quarterly or substantially every 3 to 4 years.

Nutrient removal is optional for aerobic treatment units at present. There are units available which remove the nutrients with many organisations being involved in further research in this area in Australia.

Five treatment systems approved by the Health Department of Western Australia are described here as representatives of the available systems. These systems incorporate state of the art treatment techniques available at present.

Envirocycle

Envirocycle in an aerobic treatment unit designed to treat sewage produced in a household of five people. This system has multiple treatment chambers based on the activated sludge process (Envirocycle, 1993). This is a circular unit with two primary settling chambers, two aerobic chambers, a clarification chamber, a chamber for chlorination and storage to provide enough contact time, and a chamber for storage and pumping for final disposal. The final effluent after secondary clarification and chlorination is used for spray or trickle irrigation.

Biocycle

Biocycle is an aerobic treatment system which provides a secondary level of treatment to produce an effluent which meets the 20 mg/L BOD and 30 mg/L SS effluent quality standard. This is available in two sizes. The domestic model is designed for 10 people and the commercial model is for offices, restaurants or other public institutions (Biocycle, 1990). The Biocycle treatment system consists of a circular tank which is divided into four compartments (1) primary settling and anaerobic digestion chamber, (2) aerobic chamber with fixed media and bubble aeration facility, (3) secondary sedimentation chamber with the settled sludge pumped back to the septic chamber, (4) chlorination and storage chambers. Chlorination is by tablet chlorinator and the final effluent is pumped for irrigation when the volume reaches a pre-set level. The soil at the irrigation area can be amended with neutralised bauxite residue for phophate removal.

Clearwater System

This is an aerobic treatment system which has two separate tanks. The first one is a circular tank of 1.7 m dia and 1.6 m height which functions as a sedimentation and septic tank. The second tank is a rectangular tank with three compartments, an aeration tank of 3.5 m^3, a final clarifier of 1.0 m^3 and a chlorination and storage tank of 1.7 m^3 (Clearwater, 1990). The aeration tank has panels for attached bacterial growth. The irrigation system is very similar to other systems such as Biocycle.

Aquarius

Aquarius has five chambers (1) primary sedimentation and anaerobic digestion (2) anoxic chamber for denitrification and chemical phosphorus removal (3) aerobic biological oxidation including nitrification in subsurface biofilter and dentrification in submerged filter (4) secondary clarifier and sludge recycle to the anoxic chamber (5) chlorination and storage for irrigation. In addition to the required effluent standard Aquarius claims to achieve nitrogen and phosphorus removal to below 1 mg/l. Aquarius is available in a variety of sizes starting from a domestic unit for 10 people to units for industrial use or for small communities of up to 120 population equivalent (Aquarius, 1993).

Ecomax

Ecomax consists of a conventional septic tank and dual leach drain or soakwell modified by the addition of a filter bed of amended soil with a plastic lining. The filter bed contains neutralised bauxite residue which has the capacity to adsorb phosphate, ammonium and heavy metals. The filter bed is also a good bacterial filter. The treated effluent can be disposed of by soil percolation or surface irrigation (Bowman and Bishaw, 1991). The system is designed to serve 4 - 6 people for approximately 20 years, after which the filter bed needs to be replaced. It is possible to increase the capacity of the system to serve more people or for an extended life span. This is a passive system with no requirement for power, chemicals or periodical servicing, except for the normal desludging requirements of the septic tank.

Comparison of Systems

Only systems approved by the Health Department of Western Australia are compared. As they all meet the requirements for effluent and public health standards, only special features will be discussed. All systems use a septic tank or equivalent and hence desludging will be necessary. A septic tank and leach drain requires desludging on the average approximately every 3 years. If the final effluent is used for irrigation no leach drain and its desludging is necessary. Table 2 summarizes similarities and differences amongst the systems, including initial costs and maintenance requirements.

Conclusion

Municipal reticulated sewerage and treatment systems are generally the most desirable treatment option because of the high degree of control which can be achieved and maintained over the quality and disposal of treated effluent and sludge. But when the population density is not high and if on-site disposal is possible it will be cheaper and allow better reuse options. At present more and more on-site systems are becoming available which offer similar facilities to the larger municipal treatment systems. On-site treatment systems can provide a higher degree of protection for the aquatic environment due to the use of land disposal techniques which provide additional level of treatment due to soil percolation before the treated wastewater entering the water bodies. On-site irrigation allows use of the water for evaporation and plant evapotranspiration and should not cause any pollution.

For a remote and isolated place a VIP toilet will be ideal. Composting toilets provide the ultimate answer for water conservation and complete reuse of toilet waste if maintained properly. The larger capacity of Clivus Multrum makes this system more suitable for large families or industrial application. Rota-Loo being smaller with lesser maintenance demand will be more suitable for small families. Dowmus produces a compost containing worm castings with a higher fertilizer value. It is cheaper to install and cheaper to operate as it does not require heating.

Most of the treatment units are similar and produce effluent of similar quality. Clearwater system has a separate septic tank and it is claimed that it needs to be desludged only every 10 - 15 years against a normal period of 3 - 4 years. Aquarius produces a low nutrient effluent but installation cost is higher; chemical use and yearly desludging operation also means higher operating cost. But this is available in a variety of sizes serving up to 120 people. Ecomax is a passive system which produces a low nutrient effluent but the filter media needs replacing every 15 to 20 years.

Where municipal systems are not available or costly due to low density of population on-site systems provide a variety of options. A composting system for black water and an aerobic system for grey water will assure complete reuse, conservation of water, desludging only infrequently and reduction in potential nutrient pollution.

TABLE 2: Comparison of Systems Approved by the Health Department of Western Australia

	Treatment System	Initial Cost ($#)	Maintenance Requirements	Comments
1	Clivus Multrum	3000 - 5000 plus cost for greywater treatment system	- Maintenance by the user - Cost of heating in cold areas - Power cost of fan	- Recycle of toilet waste as compost - A space of 2.5 m deep and 1.5 m wide, 2.7 m long is needed below the toilet - Saves 30% on water use
2	Rota-Loo	3000 + cost for grey water treatment system	- Maintenance by the user - Cost of heating in cold areas - Power cost of fan	- Recycle of toilet waste as compost - A space of 1.5 x 1.5 x 1.5 m3 is needed below the toilet - Save 30% on water use
3	Dowmus	2500 + cost for grey water treatment system	- Maintenance by the user - Power cost of fan	- Recycle toilet waste as worm compost - Circular area of 1.7 m diameter with a depth of 2 m is needed below the toilet - Saves 30% on water use
4	Envirocycle	5000 + installation	- Quarterly inspection - Desludging every 3-4 years - Power cost for pumps and aerators - Tablet chlorination required	- Available in domestic and commercial sizes
5	Biocycle	5500 + installation	- Quarterly inspection - Desludging every 3-4 years - Power cost for pumps and aerators - Tablet chlorination required	- Available in concrete and fibreglass in domestic and commercial sizes

6	Clearwater	5500 + installation	- Quarterly inspection - Desludging every 10-15 years - Power cost for pumps and aerators - Tablet chlorination required	- Available in concrete
7	Aquarius	8000 + installation	- Quarterly inspection - Desludging every year - Power cost of pumps - Tablet chlorination and chemical for phosphorus removal	- Available in fibreglass and stainless steel in many sizes - Removes nutrients
8	Ecomax	5500	- Desludging every 3-4 years - Replacement of redmud filter every 15-20 years	- Removes nutrients

Cost figures are in 1993 Australian $; 1 Australian $ is approximately 0.75 US $; Use of local materials may reduce costs.

References

Aquarius (1993). *"The Aquarius Micro Purifyer 600 SA Series"*. Western Wastewater Treatments Pty. Ltd., 10 Rollings Crescent, Kwinana, WA 6167, Australia.

Australian and New Zealand Environment and Conservation Council (ANZECC) (1992). *"Australian Water Quality Guidelines for Fresh and Marine Waters"* in National Water Quality Management Strategy, Melbourne, Victoria, Australia.

Bhawalkar, V. and Bhawalkar U. (1991). *"Vermiculture Biotechnology for Environmental Protection, Sustainable Agriculture Wasteland Development"* Bhawalkar Earthworm Research Institute, A/3 Kalyani, Pune-satara Road, Pune, 411037, India.

Biocycle (1990). The Biocycle Systems. *"General Information and Operation's Manual"*, Biocycle Pty. Ltd., Suite 1/231 Balcatta Road, Balcatta, WA 6021, Australia.

Bowman, M. and Bishaw, M. (1991). *"Ecomax Septic System. Explanatory Information. Ecomax Waste Management Systems"*, Bowman, Bishaw Gorham Pty. Ltd., Subiaco, WA 6008, Australia.

Clearwater (1990). *"Clearwater 90 The Ultimate in Reclaimed Water"* Clearwater Pty. Ltd., Unit 2/56 Carney Rd., Welshpool, WA 6106, Australia.

Clivus Multrum (1990). *"Clivus Solution, through Waste Technology"* Handbook and Practical Manual, Clivus Multrum Pty. Ltd., 31 Mandalay St., Fig Tree Pocket QLD 4069, Australia.

Dowmus (1993). *"Common Questions Regarding the Dowmus Composting Toilet"* Dowmus Pty. Ltd., PO Box 51, Mapleton, QLD 4560, Australia.

Envirocycle (1993). *"Envirocycle, Wastewater Treatment System"* Envirocycle Pty. Ltd. 37 Tramore Place, Killarney Heights, NSW 2087, Australia.

Health Commission of Victoria (HCV) (1979) *"Code of Practice Septic Tanks"* HCV, 555 Collins St, Melbourne, VIC 3000.

Mathew, K. and Ho. G. E. (1993). *"Reuse of Wastewater at Aboriginal Communities"*. Remote Area Developments Group, Institute of Environmental Science, Murdoch University, Murdoch, WA 6150, Australia..

National Health and Medical Research Council (NHMRC) and Australian Water Resources Council (AWRC) (1987). *"Guidelines for Use of Reclaimed Water in Australia"*. Australian Government Publishing Service, Canberra, Australia.

Odendaal, P. E. (1992) *"Water Reuse International Trend"* Australian Water and Wastewater Association Victorian Branch Conference on Wastewater Reduction and Recycling, Deakin University, Geelong Victoria, Australia.

Rota-Loo (1991). *"Rota-Loo the Waterless Composting Toilet"*. Environment Equipment Pty. Ltd., 1/32 Jarrah Drive, Braeside, VIC 3195, Australia.

Urban Water Research Association of Australia and Australia Water Resources Council (UWRAA/AWRC, 1992). *"Affordable Water Supply and Sewerage for Small Communities Investigation"*, Design and Management Handbook (Draft report).

Walker, B. (1985). *"The Introduction of VIP latrines to Aboriginal Communities in Central Australia"* Proceedings of Workshop on Science and Technology for Aboriginal Development. Alice Springs, Australia, October 1985, paper 3 - 1.8.

Secondary Treatment Systems for On-site and Decentralized Wastewater Management

Ted L. Loudon
Agricultural Engineering Department, Farrall Hall, Michigan State University, Farrall Hall,
E. Lansing, MI 48824, USA
Tel: (517) 353-3741, Fax: (517) 353-8982, Email: loudon@egr.msu.edu

Wastewater treatment processes are generally classified as either primary, secondary or tertiary. Primary treatment typically involves settlement and floatation. Secondary treatment involves aeration to promote the growth of aerobic organisms and treatment through the metabolic processes of these aerobic organisms. Tertiary treatment implies advanced polishing including more complete nutrient removal. In conventional onsite wastewater systems the septic tank serves as the primary treatment chamber, and the soil system is expected to accomplish both the secondary and tertiary treatment processes. In soils of fine particle size and low permeability, air transfer rates are limited and effective secondary treatment may occur very slowly.

The introduction of a secondary treatment device between the septic tank and the soil absorption system can greatly reduce the organic load to the soil and thus reduce the amount of treatment required in the soil system. In addition, secondary treatment generally results in effluent that is already somewhat aerobic, reducing the need for the oxygen transfer into the soil system. Therefore, adding a secondary treatment system allows utilization of soils that are normally not acceptable for onsite wastewater treatment. Secondary treatment will produce the following results:

1. Reduce or eliminate clogging at the infiltrative surface of the soil
2. Reduce the pathogen content of the effluent applied to the soil
3. Reduce the total nitrogen content of the effluent going to the soil
4. Prepare the effluent for additional treatment systems
5. Provide an effluent that is acceptable for surface discharge following disinfection
6. Provide for recycling and reuse of the effluent.

The ability of secondary treatment systems to accomplish the first three of the above results is generally recognized, but the validity and importance of the last three remain to be proven and accepted widely. In some environmentally sensitive areas, i.e., high water table soils near surface waters, phosphorous removal may be necessary beyond the level achieved with most secondary treatment systems. Concern for phosphorous removal varies from one region to another. However, once the secondary treatment system has removed most of the organic material in the effluent, it may be possible to subject the effluent to adsorptive and/or a precipitative process to further reduce the phosphorous concentration. Research is underway to test both laboratory and field performance of low management methods designed to accomplish phosphorus removal by these processes.

Some regulatory jurisdictions allow surface discharge of aerobically treated effluent following disinfection where soil properties do not provide for reliable performance of soil absorption systems. Secondary treated effluent from some treatment processes may be suitable for reuse in irrigation and/or recycling through separate plumbing back to the house for flushing. With some additional filtration and chlorination it may also be suitable for other uses.

Several recent papers have documented that secondary treatment reduces the organic loading on soils sufficiently to virtually eliminate soil clogging, allowing the use of soils of much lower permeability than would be acceptable for septic effluent (Siegrist, 1987; Tyler and Converse, 1995; Loudon and Bernie, 1995). It also allows higher loading rates and thus smaller soil absorption systems. Effective secondary treatment will greatly extend the life of a soil absorption system. Theory and experience accumulated over the past 15 years suggest that soil absorption systems may last virtually indefinitely if consistently loaded with high-quality secondary effluent. Secondary treatment may also be added where soil absorption systems are failing to renovate and give additional life (Converse and Tyler, 1994). Another advantage of secondary treatment is that various designs have been shown to provide high levels of nitrogen removal ranging to over 90 percent total nitrogen removal.

Secondary treatment systems which are in use for onsite and small decentralized wastewater treatment systems in North America include sand filters, artificial media filters, mini-trickling filters, upflow filters, and package aerobic treatment units. Sand filters and aerobic treatment units are in more common and widespread usage than the other concepts and will be discussed in more detail.

Sand Filters

Sand filters of various designs have been used for wastewater treatment for many years. Research and development over the past two decades have resulted in increased understanding of the treatment process involved and provided improved pumps, controls, distribution systems and other hardware to improve the performance and reliability of the technology.

Sand filters can be divided into several categories:

- Intermittent (single pass)
- Stratified
- Bottomless (in trench)
- Recirculating

Single pass sand filters: Single pass sand filters have been used increasingly for single family homes in the northwestern United States for over 15 years. The sand filter is an added secondary treatment device between the septic tank and the soil absorption system and requires a pump for uniform distribution of septic tank effluent over the entire area of the sand filter. A typical cross section for a sand filter includes a 24-30" deep layer of sand as the media that provides the environment for the physical, chemical, and biological transformations necessary to achieve the desired treatment level.

Suspended solids in the septic tank effluent that is pumped to the sand filter are removed by filtration and sedimentation. Bacteria which live on the surfaces of the sand particles decompose the filtered solids and, through a process known as autofiltration enhance the removal of suspended material. Reduction in BOD_5 and the conversion of ammonia to nitrate occur under aerobic conditions through the action of the microorganisms in the sand bed. Some conversion from nitrate to nitrogen gas (denitrification) routinely occurs resulting in up to 50 percent loss of nitrogen in the process. The denitrification is probably the result of anaerobic bacteria coexisting in micro anaerobic environments within the sand (Metcalf and Eddy, Inc, 1991).

To maintain a high level of treatment, aerobic conditions must be maintained within the upper portion of the sand at all times. This is achieved by utilizing only shallow, sandy soil covers or leaving the distribution stone open to the atmosphere. The pea stone layer in the bottom of the sand filter is also thought to enhance air movement from the drain up through the sand filter to further assist in maintaining aerobic conditions. Small, frequent doses of the effluent pumped uniformly over the sand is important to avoid complete saturation (i.e., pores never filled) and to maintain air within the pore space to support aerobic organisms.

In typical practice the distribution system is a small-diameter (3/4" - 1 1/4") pipe network containing 1/8" orifices spaced on a 2'x2' or 2'x3' grid. Some designers include vent pipes adjacent to the distribution pipes to assist aeration. Others cover the distribution pipes with a chamber and utilize splash plates or spray nozzles to enhance distribution over the entire surface area and enhance air transfer into the effluent.

Since small orifices are used in the distribution system (typically 1/8"), the use of an effluent filter in the septic tank preceding the sand filter is highly recommendable. The filter will help prevent things like hair and particulate material from washing out of the septic tank and thus help protect the orifices from clogging.

The choice of the sand media is crucial to the performance of the sand filter. Sands are typically specified by effective size and uniformity coefficient. The effective size (D_{10}) is the grain size for which no more than 10 percent of the particles are smaller, and the uniformity coefficient is the ratio of the size for which 60 percent are smaller to the size for which 10 percent are smaller. For single pass sand filters, an effective size in the range of 0.3 mm and a uniformity coefficient of approximately 4 are recommended. Table 1 shows a recommended grain size distribution range. Sand filter media must be free of any fines, particularly silt and clay size particles, which could contribute to possible clogging of the sand pores.

Table 1. Recommended Sand Grain Size Distribution for Single-Pass Sand Filters.

Sieve Size or Number	Grain Size (mm)	Perculent Finer
3/8"	9.5	100
#4	4.7	95-100
8	2.4	80-100
16	1.2	45-85
30	0.6	15-60
50	0.3	3-15
100	0.15	0-4

Single pass sand filters are sized based upon an assumed loading rate of approximately 1 - 1.25 gpd/sq ft. Thus a sand filter of approximately 360 sq ft would be needed for a three to four bedroom house. The dimensions in Figure 1 show that the overall depth of the sand filter is 3.5 - 4' depending on whether a soil cover is utilized.

The sand filter should be dosed frequently with small amounts of effluent to provide the desired treatment conditions. Dose amounts of less than 0.5 gal per orifice per cycle are recommended for single pass sand filters. Operating the dose pump using a timer is preferred over operating on a float switch or demand basis. Timer systems need float overrides to either run the pump more to compensate for high water use periods or keep the pump from continuing to run periodically if there is low or no water use.

Table 2 illustrates the expected performance of a sand filter compared to septic tank effluent quality. A properly designed and managed sand filter should result in essentially clear water effluent as indicated by the BOD_5 and suspended solids data. In addition, nearly complete nitrification should be achieved resulting in almost all of the nitrogen in the effluent being in the nitrate form.

The stone in the top of the sand filter around the distribution piping is there to provide a very porous matrix so that the water will move away from the distribution pipe rapidly. Typically the stone is whatever the local code requires in sewage trenches. The most important characteristic is that it be free of fines such as silts and clays that might wash down onto the sand surface and contribute to sand clogging.

Table 2. Normal Ranges of Selected Wastewater Parameters in Septic Tank and Sand Filter Effluents from Home Systems, mg/L.

	Septic Tank	ISF	RSF
BOD_5	130-250	2-10	2-15
TSS	30-150	5-12	5-20
NO_3	0-2	15-30	15-30
NH_3	25-60	0-2	0-5
Total N	25-70	15-30	15-30
Total P[2]	5-15	2-15	2-15
Fecal Coliform MPN/100ml	10^5-10^6	10-10^3	10-10^3

[1] Lower values of BOD_5 and TSS in the range are from tanks with effluent screens.

[2] Range is for locations with low phosphate detergent laws. Otherwise P concentrations may range up to 30 mg/L.

Construction of sand filters may involve plywood walls to support the required waterproof liner or, in cases where the soil is cohesive enough to stand as approximately vertical walls, the liner can be directly installed in an excavation of the appropriate size. The earth walls must be fully prepared to prevent puncture of the liner by roots or stones. In either form of construction, a 2-3" layer of sand underneath the liner to protect its integrity is recommended.

Sand filter maintenance: Regular maintenance is important to assure long-term sand filter performance. In construction, observation ports should be provided so that the infiltrative surface at the base of the stone or the top of the sand layer can be viewed to determine whether ponding is occurring at this level. It is recommended that at least one (possibly two or three) 4" inspection ports be located around the sand filter, preferably near orifices, so that the sand surface can be viewed periodically immediately following a dose of wastewater. If there is any tendency for water to pond at the sand surface for more than a minute or two, either the dose is too large, the sand too fine or the sand is beginning to clog. Sand clogging can also be an indication that the wastewater characteristics are resulting in excessive organic loading to the sand filter.

An inspection port should also be extended to the bottom of the sand filter near the outside edge, away from the drain. If the level of water ponded at the outside edge of the sand filter is more than 2-3", the drain is beginning to slow down, probably due to clogging at the entry to the drain.

Any indication of clogging at either the sand surface or the drain indicates the need for maintenance. If the clog is organic, it can probably be removed by decomposition through aeration to enhance biological activity. When sand filters are constructed, it is a good idea to provide a means for introducing air into the lower portion of the filter, either through the drain or by a buried pipe loop, typically drip irrigation tubing located at the base of the sand. It has been found that if a sand filter starts to clog, a few hours to a few days of aeration with a small compressor will provide the added bacterial activity necessary to decompose the clog and bring the sand filter back to near original performance. Clogging should always be investigated to determine the reason for the clogging and steps should be taken to eliminate the cause.

Distribution laterals should be installed with access to the end of every lateral so that laterals can be opened for flushing. Solids tend to accumulate at the ends of distribution lines, and if they are allowed to remain for long periods of time, the accumulated solids will build at the end of the pipe and eventually begin to plug the end orifices of the system. Periodic flushing at approximately six-month to one-year intervals will prevent this occurrence. Normally a provision is made to flush the accumulated solids into the stone around the distribution system where it will dry and decompose.

Maintenance should also include obtaining a sample of the sand filter effluent and having it analyzed for BOD_5, suspended solids, ammonia, nitrate, and any other constituents of concern at the particular location. BOD_5 or suspended solid levels greater than 10 mg/L or ammonia levels greater than 2 mg/L would be an indication of less than nominal performance. With experience, a maintenance person can often look at and smell a sample to determine if the sand filter is performing in a normal fashion. Therefore with experience, it is not always necessary to analyze samples in the lab after every inspection visit if all aspects of the system look normal.

Inspections should also include checking on the current draw of pumps, the performance of floats and timers in the control system, and the condition of the effluent filter. Sand filter maintenance should be performed by someone thoroughly familiar with sand filters and their operation. This will normally be someone other than the health department or the local regulator, and homeowners should anticipate a nominal fee for this service to be part of the ongoing operating cost of owning a sand filter. The area over the top of the sand filter should be always left undisturbed and untrafficked. There should not be normal walking paths over the sand filter or any use of the area over the filter for storage, construction, or any use or covering that would prevent free air movement into the sand filter.

Stratified sand filters: Stratified sand filters are generally single pass sand filters that contain at least two layers of sand media having different grain size characteristics. A layer of coarser sand is usually placed over a layer of finer sand. With this configuration, somewhat higher loading rates, either hydraulic or organic, are possible. The coarser sand will filter most of the solids and provide good air penetration for decomposition while the finer media, like that typically used in a single pass sand filter, will finish the treatment process.

Bottomless sand filters: A bottomless sand filter is an extra deep (and usually extra wide) trench that is backfilled with a layer of sand before placing the pressure distribution pipe in a stone layer under the soil surface. Bottomless sand filters or in-trench sand filters are utilized where suitable soils for wastewater disposal underlay a slowly permeable soil that is considered unsuitable for wastewater disposal.

Recirculating sand filters: Recirculating sand filters (RSFs) are typically used for wastewater flows larger than an individual home. They may also be applicable where space limits the size of the filter that can be installed for a home or where enhanced nitrogen removal is desired.

Recirculating sand filters get their name from the fact that septic tank effluent is mixed with water that has been through the sand filter and is cycled back through several times prior to discharge, either to a soil absorption system or to disinfection and surface discharge. Recirculating sand filters require a recirculation tank which contains a blend of water that has been through the sand filter and septic tank effluent. Contained in the recirculation tank is a pump operated by a timer which is set to run the pump enough time each day to pump over the sand filter several times the quantity of wastewater which is being generated. The drainage from the sand filter is then split so that a portion of it is directed back to the recirculation tank and a portion, to final disposal. Several methods are available for splitting the RSF drainage. First, a simple float valve can be used within the recirculation tank on a pipe carrying drainage from the sand filter. If the water level in the tank is high, the valve closes and all the drainage goes directly to the soil absorption system. When the water level has dropped in the recirculation tank, the water draining back from the sand filter will flow back into the tank to mix with septic tank effluent. The mix ratio in the tank is controlled by the amount of time each day that the pump runs to deliver water over the sand filter, thus determining the amount of time the valve will be open and drainage from the sand filter recycled. Other flow splitting mechanisms may be used including a flow division in the bottom of the sand filter so that a fixed portion of the drainage goes to final disposal and a fixed portion back to the recirculation tank. Flow dividing weirs or other commercially available flow splitting devices can also be used.

The sand media recommended for recirculating sand filters should have an effective size of 1.2- 2.5 mm and uniformity coefficient of 1.5 - 2.5. Recommended loading rates on a forward flow basis are 3 - 5gpd/sq ft for domestic strength effluent. Typically a recirculating sand filter for a three- to four-bedroom home would have a surface area of 100 – 150 sq ft. Smaller recirculating sand filters have been used successfully in very small yards with careful choice of media and wastewater application techniques (Pilak, 1994). Because of higher loading rates, recirculating sand filters must be open to the atmosphere so that good air penetration into the media can be achieved to assure aerobic treatment. They may have an exposed stone surface with the distribution pipe embedded just a few inches into the stone, be in a covered container with vents underneath a wooden cover, or be constructed above grade.

Some designs include a stone layer across the bottom of the recirculating sand filter underneath the treatment media in the vicinity of the drain just as in a single pass filter. It has been this author’s experience that, with the coarser media of an RSF and a drain that is vented, the treatment media can be extended to the base of the sand filter without complications.

The wastewater distribution system for the recirculating sand filter may be the same as for a single pass sand filter. However, spraying the effluent in a cavity or chamber so that the effluent is more completely distributed over the surface of the sand is a recommended practice particularly for actual loading rates of 4-5gpd/sq ft.

Table 2 shows typical performance expected for recirculating sand filters for a single family home.

Recirculating sand filters can be modified to provide enhanced nitrogen removal. One option for modification was presented by Sandy, et al. (1987) where a stone-filled cavity was provided underneath the sand filter to serve both as a mix tank and an anaerobic reactor, replacing the recirculation tank. Septic tank effluent is directed into one end of this zone under the sand filter and mixes with water that is coming down through the sand filter as it flows across to the other side where it is pumped either back over the filter or, periodically, to final disposal. The water coming through the sand filter will have the nitrogen mostly converted to nitrate; and, as the nitrate mixes with the septic tank effluent, an adequate carbon source is provided to assist in denitrification. Total nitrogen removal rates as high as 90 percent were reported by Sandy, et al. (1987).

Another option to enhance nitrogen removal is to simply direct a portion of the nitrified affluent from the sand filter back to the septic tank to mix with the organic source there to promote denitrification. Adequate capacity must be provided in the septic tank to prevent the added flow through the tank from reducing solids removal efficiency. An effluent filter on the septic tank is highly recommended for this application.

A third option would be to add a separate denitrification tank where either grey water or a separate carbon source such as ethanol could be mixed with the nitrified sand filter effluent to promote denitrification. However, unless the denitrified effluent is then passed through another sand filter or other process to remove BOD_5 added by the carbon source, it may cause more soil absorption system clogging than RSF effluent.

Maintenance of recirculating sand filters: Maintaining recirculating sand filters is about the same as maintaining single pass filters except that the sand surface and distribution piping of the system are much more accessible to monitor and/or maintain. Small diameter distribution laterals need to be flushed to remove solids and prevent orifices from plugging. Monitoring tubes need to be provided to check for clogging at the surface of the sand treatment media and to check for possible increases in the saturated zone depth in the bottom of the filter that might indicate clogging at the drain. Provision for aeration from the bottom up is recommended. This is just a precaution so that air can be induced if the system does at some time begin to clog or slow down hydraulically. Leaves and other litter need to be kept off the stone surface so that soil does not start to build and provide a receptive surface for weed seed germination. Occasionally a weed seed may germinate and start to grow even on the stone surface and should be removed as soon as noticed.

The stone surface over a recirculating sand filter can be a landscaping asset. It can be a base for decorative objects, flower boxes around the edge and shrubs just off the edge. However, most of the surface area must be left sufficiently open for air penetration into the treatment zone.

Aerobic Treatment Units

Package aerobic treatment units have been used for many years to provide enhanced treatment and overcome soil and environmental conditions which are not suitable for the use of conventional septic systems. These units continue to improve, and a number of very reliable systems are available. The aerobic treatment unit (ATU) industry has worked with the National Sanitation Foundation in Ann Arbor, MI to develop a testing protocol whereby aerobic treatment units can be tested and certified to meet a certain level of performance. The testing protocol, NSF Standard 40 (1996), requires that for a unit to be NSF certified, it must be operated and monitored by NSF for a period of six months at a facility that they maintain and must meet established minimum treatment standards.

Aerobic treatment units include pretreatment in a primary settlement chamber which is either a part of the unit or required as a separate tank. Following the primary treatment chamber, wastewater flows into the main treatment chamber where aerobic organisms decompose suspended and dissolved organic substances. The objective of the hardware and tank geometry of an ATU is to create an environment where microorganisms which are naturally present in the wastewater will grow and treat the wastewater by consuming the organic matter. This environment is created by a process of continuously adding air to replenish dissolved oxygen in the wastewater as it is consumed by the organisms and mixing to provide contact between the organisms and the wastewater contained substances that are to be consumed. ATUs are also designed to provide for settling and removal of solids remaining after the aerobic treatment process. This occurs either in a separate clarifer following the aeration chamber or as a part of the specific geometry of the aeration chamber itself. Some include a filter to assist the solids removal process.

For purposes of this paper, data generated during the standardized testings of the National Sanitation Foundation certified aerobic treatment units are presented to provide a reliable indication of the potential wastewater treatment results which are achieved when systems are operating according to the manufacturers’ specifications and under a standardized loading criteria and wastewater strength. The National Sanitation Foundation Standard 40 under which ATUs are tested requires that the wastewater influent to the test unit have a carbonaceous BOD_5 concentration between 100 and 300 mg/L and a total suspended solids concentration between 100 and 350 mg/L. ATUs are tested for a period of 26 consecutive weeks. During the testing and evaluation period, the system is subjected to 16 weeks of design loading followed by 7.5 weeks of stress loading simulating four different stress conditions and then a second phase of design loading for 2.5 weeks. Stress conditions simulated include a wash day stress, working parent stress, power outage or equipment failure stress and a vacation stress. The inflow regime for the 16 weeks of design loading requires 35 percent of the rated daily hydraulic capacity be added to the system between 6 and 9 a.m., approximately 25 percent added between 11 a.m. and 2 p.m. and the remaining 40 percent added between 5 and 8 p.m. to simulate a typical daily loading from normal activities of a contemporary active family. No routine service or maintenance is allowed on the system during the data collection time. Additional details regarding the testing protocol are available from NSF (1996).

Ten manufacturers who are marketing ATUs with NSF certification were contacted for information on their NSF test results. Seven manufacturers responded and provided their NSF Standard 40 test results reports. The reports provide detailed data on system performance on a day to day basis over the approximately 28-week testing period.

Table 3 presents a summary of average values obtained for BOD_5, suspended solids, temperature, dissolved oxygen and, where available, nitrogen removal results. Data from eight different units representing seven different manufacturers are included in the summary table. Four of the units are systems which depend upon extended aeration and activated sludge processes as the treatment mechanism. Each of the other four units reviewed involve a somewhat different process. They are described respectively as 1) extended aeration activated sludge with filtration, 2) mechanical aeration with filtration, 3) attached growth aerobic-fixed film anaerobic, and 4) attached and suspended growth.

Testing for nitrogen removal is an optional extra. None of the extended aeration activated sludge plants included nitrogen removal data in the report. Of the other four units in the table three were tested for nitrogen removal. In the activated sludge process, microorganisms remove soluble contaminants from the wastewater utilizing them as a source of energy for growth and production of new microbes. The organisms tend to be flocculent in nature and form settleable clumps that also entrap particulent organic matter. The organic matter are attacked by extracellular enzymes that solubilize the solids to make them available to the microorganisms as a food source. The conversion of the organic matter from soluble to biological solids allows for removal of the organic matter by settling of the biological cells in the treatment process (Grady and Lim, 1980).

Extended aeration is a modification of the activated sludge process in which microorganisms are allowed to remain in the treatment process for long periods of time. The large amount of biological solids in the process provides a buffer for shock loading of organic matter. The long aeration period allows for the organisms in the system to consume themselves, reducing the total amount of solids produced by the treatment process (NSF, 1996). The activated sludge process is referred to as a suspended growth system. Interruption of the aeration process for a long period of time can have serious impact on the process.

Some of the units are designed to provide an environment for denitrification following the aerobic treatment system. This process requires the aerated effluent to be subjected to anaerobic conditions containing an energy source (carbon source) and denitrifying bacteria. These processes are accomplished in various ways in the various proprietary systems. Table 3 shows that some systems were able to achieve a high level of total nitrogen reduction.

The day to day data in the test reports generally show very consistent performance with BOD_5 and suspended solids usually less than 10 mg/L in the final effluent and often less than 5 mg/L. Some units showed more response to the stress loadings than others in terms of the occurrence of elevated BOD_5 and suspended solids concentration in the effluent. For a plant to achieve certification as a product producing class 1 effluent, it must produce an effluent that meets the EPA guidelines for secondary effluent discharge. The 30-day average BOD_5 concentration of effluent samples must be below 25 mg/L. The seven-day average carbonaceous BOD_5

concentration must be less than 40 mg/L. The criteria for total suspended solids are that the 30-day average must be less than 30 mg/L; and the seven-day average, less than 45 mg/L. The data for all the plants reviewed showed performance results well below these maximum criteria levels for class 1 status.

Table 3. Aerobic Treatment Unit Performance Data Obtained During NSF Testing; Values are Averages over the 28-week Test (all values mg/L except temperature).

Treatment Type	Extended	Aeration	Activated	Sludge	Extended air activated sludge w/filter	Attached Mechanical Aeration Filtration	Film Annaer.	Growth
BOD_5								
Influent	173	184	148	176	146	143	159	144
Effluent	6	10	14[1]	7	6	13	5	9
Susp. Solids								
Influent	189	209	193	213	195	215	182	197
Effluent	7	9	48[1]	14	6	17	5	7
Avg. Temp. (° C)								
Influent	17	18	12	17	12		13	12
Chamber	16	17	10	18	13	16		
Effluent	16	17	10	14	11		11	11
Dissolved O_2								
Chamber	1.4	5.0	5.7	8.0		8.9		2.1
Effluent	3.1	2.2	3.0	7.1		6.4		3.7
Nitrogen Ammonia								
Influent						22		
Effluent						1.8		

Treatment Type	Extended	Aeration	Activated	Sludge	Extended air activated sludge w/filter	Attached Mechanical Aeration Filtration	Film Annaer.	Growth
Nitrate								
Influent						0.5		
Effluent						15		
Total N								
Influent						33.5		
Effluent						19.9		

[1]High effluent BOD_5 and S.S. values were caused by 4 consecutive days of high output values. If these 4 days are omitted, avg. BOD_5 is 6 mg/L and avg. S.S. is 8 mg/L.

The test data show ATU effluent quality in the same range as sand filter effluent. Converse and Tyler (1994) showed that ATU effluent discharged to a failing septic soil absorption system has the capacity to result in renovation of the clogging and subsequent reliable performance.

Maintaining Aerobic Treatment Units: Just as with other secondary treatment processes, regular monitoring and maintenance of ATUs is required to assure that the units continue to provide a high level of treatment and good effluent quality. Manufacturers literature provides recommendations on service intervals and components to be checked. Recommendation are provided to help users understand what is and is not appropriate to be flushed into the system. Owners are cautioned to be alert for change in the sound of system operation or system odor that may be early indications of a need for service. Service intervals are specified for checkups by a qualified service provider.

Waterloo Biofilter

Jowett (1995), reported on the development of the Waterloo Biofilter which is a device using open cell urethane foam similar to the material used in the trickling filter in a configuration very much like a recirculating sand filter. For a home this system can be housed in an above grade structure of about 32 - 36 sq. ft in floor area or below grade in a septic tank. Septic tank effluent is pumped over the synthetic media in small bursts and the effluent from the media is partially circulated back to the septic tank or a pump chamber and partially discharged to a soil absorption system or other final discharge receptor. Mechanical air circulation within the biofilter container is required in order to achieve nitrification levels similar to those achieved with a sand filter. The Waterloo biofilter is a proprietary system that is being marketed in Ontario having been approved by the Ontario Ministry of Environment (Jowett, 1996).

Other Systems: Numerous other systems are being utilized to provide secondary treatment in onsite and small decentralized wastewater treatment settings. Most have not yet been a subject of detailed published information. Technologies such as upflow filters, peat filters, geotextile filters, expanded aggregate sand filters, and other systems are being utilized and have been reported to provide treatment results comparable to the secondary treatment concepts discussed here. These also appear to be very promising technologies for the future.

Expectations and Needs

The potential for enhanced use of existing secondary treatment technologies and development of other similar technologies for onsite and small decentralized wastewater treatment systems is promising. With reliable equipment readily available--including pumps, controls, automatic valves and various plumbing schemes easily fabricated with plastic pipe--the options are many. Small-scale secondary treatment processes have proven that final effluent quality rivaling that of large municipal wastewater treatment plants is achievable. These systems provide the opportunity to utilize slowly permeable soils for completing the wastewater treatment process or may be approved for surface discharge following disinfection where appropriate. Many soil conditions not currently approved for septic effluent disposal have the capability of reliably removing nutrients and completing the pathogen removal process so that protection of public health can be assured and environmental degradation virtually eliminated.

One issue remains to be solved for certain sites adjacent to sensitive inland waters where phosphorous is the major issue of concern. None of these systems have been shown to reliably remove phosphorous to levels required for discharge around sensitive inland lakes and streams. However, this issue is currently being addressed by researchers in several parts of the world.

Reliable secondary treatment with regular maintenance programs will provide very long term continuing high quality treatment and environmental protection without the need to expand expensive central collection and treatment facilities. Proper use of this technology also can provide a tool for local zoning administrators to plan and control development rather than letting it sprawl over the countryside with allowable development sites dictated only by the most permeable soil conditions. Utilizing secondary treatment to remove the potential for wastewater to clog soils provides the opportunity to utilize soils that have long been passed over as undevelopable until the sewers arrive. It is important for practitioners in all sectors of the wastewater treatment community to become familiar with these technologies and trained on their proper use. It is imperative that maintenance organizations develop to take care of these systems so that they can provide long- term, effective treatment for the owners.

References

Converse, J. C. and E. J. Tyler. 1994. Renovating failing septic tanks--soil absorption systems using aerated pretreated effluent. In: Onsite Wastewater Treatment Proceedings of the 7th International Symposium on Individual and Small Community Systems, pp. 416-423. American Society of Agricultural Engineers, St Joseph MI 49085.

Grady, Jr., C. P. and H. C. Lim. 1980. Biological wastewater treatment: theory and applications. Marcel Decker publishers, New York.

Jowett, E. C. and M. L. McMaster. 1995. Onsite wastewater treatment using unsaturated absorbent biofilters. Journal of Environmental Quality. 24:86-95.

Jowett, E.C. 1996. Personal communication.

Loudon, T. L. and G. L. Bernie. 1991. Performance of trenches receiving sand filter effluent in slowly permeable soils. In: Onsite Wastewater Treatment, Proceedings of the 6th National Symposium on Individual and Small Community Systems, pp. 313-323. American Society of Agricultural Engineers, St Joseph, MI 49085.

Metcalf and Eddy, Inc. 1991. Wastewater engineering: treatment disposal and reuse. Revised by G. Tchodanoglous and F. C. Burton, pp. 1035-1037.

NSF International Standards 40. 1996. Residential wastewater treatment systems. NSF International, Ann Arbor MI 48113.

Sandy, A. T., W. A. Sack and S. P. Dix. 1987. Enhanced nitrogen removal using a modified recirculating sand filter (RSF^2), In: Onsite Wastewater Treatment, Proceedings of the 5th National Symposium on Individual and Small Community Systems, pp. 161-170. American Society of Agricultural Engineers, St Joseph MI 49085.

Siegrist, R. L. 1987. Soil clogging during soil surface wastewater infiltration as affected by effluent composition and loading rate. Journal of Environment Quality, 16: 181-87.

Tyler, E. J .and J. C. Converse. 1995. Soil acceptance of wastewater affected by wastewater quality. In: 8th Northwest Onsite Wastewater Treatment short course, pp. 96-109. Seattle.

ATU manufacturers who provided data:

> Aquarobic International
> Bio-Microbics, Inc.
> Clearstream Wastewater Systems, Inc.
> Clearwater Ecological Systems, Inc.
> Delta Environmental Products, Inc.
> Hydro-Action, Inc.
> Norweco, Inc.

[1] *Professor and Extension Agricultural Engineer, Michigan State University; President-elect, National Onsite Wastewater Recycling Association (NOWRA)*

Affordable Household Systems for Community Sanitation

Stephen Hodges
Construction Resource and Development Centre, 11 Lady Musgrave Avenue, Kingston 10, Jamaica
Tel: (876) 978-4061, Fax: (876) 978-4062, Email: crdc@jol.com.jm

I would like to speak about my experiences with Community Sanitation in two squatter upgrading sites in Montego Bay, Roseheights and Norwood over the period 1995 until the end of last year. Before that time, neither myself nor Construction Resource and Development Centre, the NGO I worked with, had particular experience with community sanitation and its attributes. Nearly three years later, I hope to be able to point to where, given our circumstances, we feel we should go next. Along the way, I will try to draw out the issues to do with the household systems I felt we, myself and the Sanitation Support Unit of CRDC learnt about.

The site was all limestone hills, where several pre-project activities had occurred. Bore holes had been done, an assessment of the environmental impact of the proposed upgrading works, particularly the putting in of roads and water, and a survey of all the lots to see what types of disposal facilities they had, and some measure of the household's preferences.

A mix of latrines and water bourne solutions were in place, many not discharging into an acceptable place, and 19% had no sanitation solution whatever. The use of "Lada bags" as a disposal technique gets less and less acceptable for neighbors as the density of a settlement rises.

There had also been an attempt to set design standards for sanitation systems for the site, which had built six demonstrations VIDP's along with a greywater disposal system. As a follow up to this attempt, the SSU had as one of its first tasks the countering of the rumour that they had come to impose VIDP's on the community. The resistance to the VIDP's was surprising, as the demonstration units had been well received. We can only presume that this was because of a particular attribute of a VIDP in Jamaica, that they are free. We do not know of one VIDP that has been paid for by its user, and this rather skews how they are accepted. Indeed, communities from all over the island who need help with sanitation now ask funders for VIDP's, even where this is not the optimum solution. The fact that the SSU was not offering anything free, but had a credit programme to allow the householders to acquire a facility if they needed one, gave, we feel, a much more accurate measure of the acceptability of the menu available.

SSU set out to develop a menu of solutions that would fit the site conditions as well as the ability to repay the loans available. This included single ventilated latrines, composting toilets, VIDP's, absorption pits as well as septic tanks and tile fields or soakaways, and discussions were held about the possibility of condominial septic tank systems for groups of houses on difficult sites.

The menu rapidly shrunk to a single item, the absorption pit, providing for a flush toilet (a supply of low cost, low flush WC's was brokered through a hardware store). The community was obviously looking up, they were likely to own the lot they were living on after the upgrade, and they knew what they wanted. There has never been much of a niche for intermediate technology in Jamaica, probably because it is too easy to set ones standards by relatives up north, or at least from "Days of Our Lives". Practically, one can hardly blame them, as water was coming into the community, and a pit would cost around the same as a VIDP.

From other experience, VIDP's come with a second drawback in Jamaica, in that they are new technology, and there is no culture of emptying latrines. Three years after building VIDP's one

has the task of education of the owners on how to deal with the waste, as one cannot effectively teach this when they are new and empty.

Somewhat to the amazement of our technical backup from the Environmental Health Project, as well as some of the officials from the Ministry of Health, we found soil or marl or fine granular material on almost all of the lots we worked with. As we knew of the number of sinkholes that were in use for sewage disposal, we had assumed that we would not be able to dig a hole without finding solution hollows. In reality, the holes, where we did find them, were obvious, and could be sealed up. It became one of the tasks of the SSU technical officers to inspect the pits that were dug to look for any evidence of solution hollows. Technical advice was sought from several of the government agencies to set the standards for the pits, ending up with simple rules for distance to solid rock. Percolation tests were organised in the bottom of pits in new areas, to stay within code. Despite an approach that sought agreement from wide ranging technical expertise and officialdom, the SSU gets criticized to this day for not "sealing the pits", which in a water bourne system, would not have helped anyone.

The rest of the SSU approach drew less criticism, and indeed a lot of praise. The team set up a service oriented unit which saw the householders somewhat as clients, and charged up to 7.5% of the loan amount for a range of services, including inspection, design, siting, arrangement of a contractor, site inspections, payment services connected to the loan, acquiring a list of materials from the hardware to assist in completion of a bathroom structure and final inspection by the Public Health Inspector. In addition, the unit ran a public education programme, working with the community on their problems, trained and supported a team of community animators who continued in the community when SSU moved on, and monitored several indicators of public health significance. Because of some disposal problems, the SSU is now working on greywater disposal issues in the community, and trying to produce some training materials.

Having more than satisfied the numbers targeted, achieved near full cost recovery and put aside a useful amount as a sustainability fund, CRDC has kept the SSU open to look for work in community sanitation.

I should at this point make a plea for credit to be available for sanitation purposes. The SSU proved that a unit can make good use of credit in doing sanitation work, particularly in achieving cost recovery while producing substantial numbers of acceptable solutions.

CRDC is hoping to interest some of the government agencies in assisting with credit so that the collaboration that was achieved in the Montego Bay project can be continued to the many other communities needing help. We have started a project, ACES (Advancing Cooperation in Environment and Sanitation) to assist with the training, information, designs, advocacy and persuasion needed to get other agencies active in the sanitation field, and to bring in some organisations who should be active.

That leaves me to deal with some left over technical questions. Can anyone give a judgement on how much nutrient load comes from VIDP's when they are emptied and spread on plants, vs. absorption pits and septic tanks. Is the only solution to collect and treat, apart from no one living on the land? We felt particularly exposed having to make compromises, take decisions with the community as a partner, with little data to back us up. Is it really impossible to have a water seal and be environmentally friendly?

PART 2

COUNTRY REPORTS

Regional Workshop on Application of Environmentally Sound Technologies for Domestic and Industrial Waste Water Treatment

David A. Matthery DPH, CPA, BSc (UWA)
Senior Public Health Inspector, Ministry of Health and Civil Service Affairs, Antigua, 1998

Introduction

The disposal of raw sewerage into freshwater and the marine environment will inevitably threaten the public health of any country. The growing standard of living and increased industrialization, including tourism, has resulted in more and more wastewater to be disposed of. Antigua and Barbuda have no central sewer system. However, several types of individual systems are used. Notably, the **Bucket system** (night soil system) **Pit Privy**, **the Septic Tank and Soak-a-way** and the new **Sewerage Packaging Plants**.

The twin island state of Antigua/Barbuda suffers severely from droughts. Within the last ten years the annual rainfall was some meager 36-42 inches per year. With a thriving and expanding tourism industry and a daily water consumption rate of 3.8 million gallons per day, means that an alternative source of water is needed to supplement the scarcity of rainfall. Thus, to meet the daily demand rate seawater is desalinized. Wastewater in Antigua/Barbuda is mainly generated form septic tanks systems, sewage plants and to a lesser extent some small industries such as paint production, distillery and brewery. The potential threat of marine pollution from sewage contamination has far reaching implications for public health.

Sources of Pollution

Bucket System – The Central Board of Health a division in the Ministry of Health presently operates this system for a very small percentage of the population. Human excrements are stored in pails/buckets and are collected from the residents during the period of 10.00 p.m. to 5.00 a.m. The waste is transported to the dumpsite where it is buried in shallow trenches two feet deep. There are 220 residents using this system, which from time to time experience some difficulties in its regular and efficient management. Thus, illegal collection and disposal methods, result in raw excrement being disposed on in the marine environment and open drainage.

Septic Tanks – This system is used by approximately 65% of the resident and commercial sector in the country. Within the city of St. John's the predominant soil structure is clay and land space for building construction (residential and commercial) is very limited. This situation has caused the average septic tank to be undersized in relation to the number of bedrooms/bathrooms. Also, very little attention is being paid to the permeability of the soil. As a result of this action there has been a proliferation of effluent flowing from one building to the next, creating several wastewater nuisances in the country. To alleviate some of these nuisances the wastewater is channeled to the street drains en route to the sea.

Packaging Plants – The result of a survey conducted by the Caribbean Environmental Institute (CEHI) and the Pan American Health Organisation (PAHO) in 1992 revealed that 88% of the sewage packaging plants operate below standard. Further, the result notes that 12% of the plants operate good. 35% operate moderately, 24% operate poor and 24% of the remaining plants are not operational.

The effluent at 12 of the plants are chlorinated before disposal. At few of the plants chlorine tablets are placed in the clarifier overflow to disinfect the effluent, this is a very ineffective means of disinfection. The effluent from these plants are disposed of directly into the marine environment, salt water lagoons, and into street drains. In some instances it is recycled for irrigation.

Implications for Public Health

There are several bacterial, viral, rickettsial and helminthis communicable diseases that are transmittably by environmental agents and vectors, which has the potential to sustained in humans by the pathogens that live in the excreta of an infected person, and find their way by water, food or soil to another human being. "The continued careless handling of human excreta maintain these diseases". Septic tank system has the potential to achieve hygenic objectives admirably, and it is easier to keep clean and free of odour, when compared to the pit privy. The controversy with the septic tank system in Antigua/Barbuda is not their hygienic failure, but their failure as a disposal process, squeezed into small lots in soil of limited permeability.

In St. John's effluent from septic tanks are discharged either directly, or through a seepage pit, to street gutters and other open drainage. This effluent at best, has only received primary treatment. Gray water from bathing, laundry, sink etc., usually is piped directly into the gutters and open drainage en route to the bay.

Typhoid and infant gastroenteritis are two disease indicators of unsanitary sewage/excreta disposal problems. According to a 1985 PAHO workshop report, 60% of the annual gastroenteritis cases are reported from the St. John's population, where unsanitary sewage systems are found.

Institutional Framework

The Central Board of Health (CBH) in conjunction with the Development Control Authority (DCA) have been reviewing all plans for new developments in the island. With the past five years a total of 4,194 plans have been reviewed and pass. The following percolation rates (table 1) are being used based on the soil type.

Table 1. Percolation rates for Antigua/Barbuda

Type of soil	Rate per minute/inch
Clay	Over 60 min/in
Volcanic	25 min/in
Topsoil	20 min/in
Marl	18 min/in
Loam	14 min/in
Limestone	13 min/in
Topsoil/Clay	35 min/in
Topsoil/loam	34 min/in
Topsoil/Marl	10 min/in

The size of the septic tank is calculated based on the number of bedrooms and an average of 30 gal./per person/per day usage of water, when only wastewater from the toilet is going to the septic tank. When all wastewater are to be disposed of into the septic tank then the criteria is calculated using a minimum of 60 gal/per person/per day (Table 2).

Table 2.

Toilet water only 30 gal./per person/per day	All waste water combined 60 gal./per son/per day							
# of Bedrooms	**Vol.gal**	**Liq. D**	**Ext. L**	**Ext. W**	**Vol.gal**	**Liq. D**	**Ext. L**	**Ext. W**
*2	720	4’	10’–0"	3’-10"	720	4’	10’-0"	3’-10"
*3	720	4’	10’–0"	3’-10"	1080	4’-6"	12’-0"	4’-0"
*4	720	4’	10’–0"	3’-10"	1440	5’-0"	12’-3"	4’-6"
5	900	4’	11’-0"	4’-2"	1800	5’-0"	13’-6"	5’-0"
6	1080	4’-6"	12’-0"	4’-0"	2160	5’-0"	14’-7"	5’-4"
7	1260	4’-6"	12’-6"	4’-6"	2520	5’-0"	15’-8"	5’-8"
8	1440	5’-0"	12’-3"	4’-6"	2880	5’-0"	16’-7"	6’-0"

* the minimum capacity for any septic tank in Antigua/Barbuda is seven hundred and twenty gallons.

Monitoring of the environment

The CBH department of the ministry of Health has been monitoring the near shore environment to ascertain its status from since 1989 in conjunction with the Caribbean environmental Heath Institute. The feacal coliform, feacal streptococcus ratio is been used as indicators of the level of pollution. Four categories are used;

(1)	FC:FS>4	- Pollution from human wastes
(2)	FC:FS<0.7	- Pollution from livestock or poultry
(3)	FC:FS 2 to 4	- Mixed pollution but mainly human
(4)	FC:FS 0.7 to 1	- Mixed pollution but mainly livestock or poultry

The samples generally falls into category 2 which denotes that the pollution present are of livestock or poultry. The areas mainly monitored are recreational beaches.

The majority of the hotels and some business places employ the use of sewage packaging plants on the islands to date there are 34 such plants. A survey in 1994 by PAHO revealed that 88% of these plants are not functioning properly, that is effluent with a BOD of 30 mg/l and SS of 30 mg/l.

Environmentally Sound Technology

When one focuses on a new technology and seek to determine whether or not such technology is appropriate or environmentally sound for their situation a number of variables must be taken into consideration, such as;

Functionality and process performance
Sustainability
Cost and affordability

Functionality and process performance relates to the ability of the technology to improve public health and environmental conditions under the existing conditions. The technology must have the ability to remove the present pollutants and assuring safe disposal of the liquid and solid output. The sustainability criteria of the new technology must ensure the potential exist for continuous operation of the facility in the future.

The final point I want to mention here is the notion of cost and affordability, before the implementation of any new technology we must ascertain whether or not it is cost effective when compared to another technology.

References

Caribbean Conservation Association
The Island Resources Foundation, Environmental Agenda for the 1990's, Sept. 1991.

Antigua and Barbuda Environmental Profile, April 1991.

CIBA-GEIGY Corporation
Caribbean Desalination, A technical operational seminar, Aruba 1991

CEHI/PAHO
Assessment of Operational Status of WasteWater Treatment plants in the Caribbean, December 1992

Chanlett, Emil T., Environmental Protection, McGraw-Hill Book Company, 2nd edition, 1979

Chemistry and Food Technology
Dunbar Scientifica, Ministry of Agriculture, Fisheries, Lands and Housing., Dunbars, Antigua, Vol 2, No 1, 1991.

Davis, Mackenzie L./David A. Cornwell, Introduction to Environmental Engineering, McGraw-Hill series, 2nd edition, 1991

1. Freedman, Ben., Sanitarian Handbook, Theory and Administrative Practice for Environmental Health, Peerless Publishing Co., 4th edition, 1977.
2. PAHO/WHO, Workshop on the Operation and Maintenance Waste Water Treatment Plants, Antigua., Aerobic Biological Systems, 15-18 November 1994.
3. Salvato, Joseph A., Environmental Engineering and Sanitation, Wiley-Interscience Publication, 1982.
4. Wagner, E.G. and J.N. Lanoix, Exreta Disposal for Rural Areas and Small Communities, WHO Geneva, 1958.

An Integral Approach to Wastewater Management is a Necessity Than a Choice For Small Islands

(A View From a Policy Maker)

Dr. Ing. Elton L. Lioe-A-Tjam
Directorate VROM, Government of Aruba, Wayaca 31-C, Oranjestad, ARUBA
Tel: 297-832345, Fax: 297-832342, Email: vromaua.dir@setarnet.aw

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Drs. Ing. Elton L. Lioe-A-Tjam
Director of the directorate of VROM,
Ministry of Justice and Public Works
Adjunct professor of MAPTS,
University of Anchorage Alaska.

Introduction

The concerns for untreated wastewater dates back to the Roman empire were sewer lines to some extent were separated from drinking water. Much later in Paris the need of sewer lines was severely felt as a result of urbanization. The increased population brought along more unhygienic events and sicknesses. Paris was forced to implement the first 'modern' sewer line system in the world. Many other cities followed. The implementation of sewer lines meant the direct solution to the hygienic aspects in the direct surroundings of the cities, but it didn't solve the problem as the wastewater was discharged 'further down the line'.

The discharge of raw water is in fact not a problem if the receiving waterbody is 'capable' enough to handle the discharge. This means that the natural biological purifying capacity (buffering capacity) is capable of dealing with the 'foreign substance that is been put in the waterbody.

Wastewater treatment has evolved in three phases.

Phase 1: Hygienic aspects. In this phase the accent was laid on the removal and treatment of rough, floating fecali that poses a threat to human health. Treatment plants were designed to treat raw water;

Phase 2: Environmental aspects. In this phase environmental concerns were added. An example is the measures to reduce nutrification of waterbodies as a result of treatment plants effluent discharges;

Phase 3: Effects aspects. The accent shifted in this phase to the toxicity of effluent discharges (enriched or not with precipitation chemicals) on organisms.

The objective of this paper is not to discuss the technical aspects of wastewater treatment, but it deals with the management aspects that are often considered as a separate process. This paper will discuss the issues that small islands have with wastewater management and the necessity of an integral approach.

Urbanization

The last two decades the economies of most Caribbean islands have grown primarily because of the shift or introduction of tourism. This however didn't change the overall economic structure. Most of the islands remain a 'single economic pillar' economy with little diversification. This simple economic structure has given many of these islands a higher standard of living.

Associated with economic growth comes also:

- an increase in population;
- an increase of foreign visitors;
- an increase of land use;
- an increase of waste (solid as liquid).

Caribbean islands economic developments can be divided in:

1. 'classical';
2. 'modern'.

Ad 1. These types of developments has an historical background i.e. 'cities' were formed around the economic center's.

Ad 2. These types of developments are been established 'scattered' over the landscape e.g. tourism developments.

Both developments have the function of 'pull-factor's, which means that settlements (residential and/or commercial) will be developed in the vicinity of these developments. The result of this is the forming of a wider area network of settlements. Besides this 'network effect', developments also induce a stronger income stratification. This stratification is translated in 'urban sprawl'.

Water

The majority of the Caribbean islands use ground or surface water as potable water. Surface water also has other functions in the rural area e.g. the washing of clothes in rivers and streams transport. The replenishing of these waterbodies is solely dependent on rainfall.

An ever increasing amount of users (resident or alien) means:

- higher land claims;
- conflicting functions;
- higher water usage;
- depletion of waterbodies.

Many of the new developments can be located above an aquifer or alongside a river or stagnant waterbody, with the possibilities that the waterbody can be contaminated or depleted.

The use of water will eventually result in the discharge of raw water. This discharge can be done by surface run-off, infiltration or direct discharge in the waterbody. Water will always seek the lowest point of energy and will accumulate at this level. If raw water is discharged by the first two ways, the travelling time and filtration through these mediums will reduce the ‘load’ to the receiving waterbody. However these types of discharges has hygienically implications attached depending on the load and the method used. Time, purifying capacity and ‘loads’ determines the function of the waterbody.

Many waterbodies on some islands have multiple functions. Water management is required.

Infrastructure

Wastewater treatment is a very costly business giving the fact that sewer lines and plants has to be installed to reduce environmental problems. The costs varies depending on:

- the type, method of and amount of lines;
- the treatment plant design.

Urban sprawl and scattered planning have led to large surface areas in which sewer lines and plants has to be developed. This aspect is one of the major factors in the costs in implementing waste management policies.

In addition depending on the landuse policy, often the required land is not owned by government, which will lead to higher cost.

The aspect of plant design is crucial. The design of the plant not only determines the amount of land that is required, but also the maintenance and skilled labor. A complex plant requires high maintenance and qualified labor to operate the plant. A lack of any of these to components will eventually lead to a not optimum functioning plant (technology management).

Case: Wastewater treatment in Aruba

Island description

- Population: ca. 93.000 inh.;
- Visitors: ca. 750.000/a;
- Households: ca. 26.000;
- Hotel rooms: ca. 7000
- Surface: 181 km^2.

Current wastewater situation

- Desalinated water is used for all uses e.g. washing etc. Water consumption is 170 l per person per day;
- Most of the produced wastewater is been discharged into septic tanks (decentralized collection). A part of this is being used for irrigation purposes, the rest infiltrates into the ground;
- 26% is collected and transported to the treatment plant;
- 6% of the household wastewater is discharged untreated directly into the sea;
- by heavy rainfall the surplus is discharged into the sea;
- thermal process cooling water is discharged daily into the sea by the utility company (36.000 m^3) and the oil refinery (60.000 m^3);
- two treatment plants (35.000 i.e. and 15.000 i.e.). Plant types are activated sludge with UV-treatment and compactor system.

Current bottlenecks

- the majority of the existing sewerlines has exceeded its technical lifespan. It can be assumed that all of these lines must be replaced.
- insufficient pumping capacity;
- limestone underground;
- mixed sewer line system i.e. rain and raw wastewater in one sewer line system.

Initiated activities

- Inventarisation of current system;
- Master plan design 'Afvalwaterstructuurplan Aruba 1997-2010';
- Drafting of the necessary legislation;
- Integration of various policy plans e.g. National Environmental Policy Plan 2000-2005 (draft);
- Designing of automated monitoring systems and parameters.

Proposed Effluent Quality Standards

Parameter	**Unit**	**Nature site**	**Irrigation site**	**Sea**
BOD	mg/l	<20	<20	<20
N_{tot}	mg/l	10	--	--
P_{tot}	mg/l	<3,0	--	--
TSS	mg/l	15	<50	<15
E.coli	n/100 ml	10^3- 10^5	<10^2	10^3- 10^5

An Integral Approach

Implementing wastewater management policies implies a 'total chain management'. This means looking at issues at the source and at the discharge, integrating other disciplines than only looking at the technological side. Examples of the other disciplines that directly is related to wastewater management are:

1. planning;
2. legal;
3. social.

Ad 1. *the location of the treatment plant is dependent on landuse, the zoning functions and regulations and the existing facilities e.g. landfills. Here is where physical planning plays a crucial role.*

Ad 2. *proper and adequate legislation is necessary to provide the legal framework that is required.*

Ad 3. *involvement of the community is essential to prevent 'myth's' and to stimulate other related programs associated with the treatment facility e.g. water consumption reduction programs*.

In basic the procedures that must be followed in implementing an integral management system are:

1. typifying sources i.e. diffuse or point;
2. designing policies i.e. master planning;
3. drafting legislation;
4. development of support decision tools;
5. implementing and monitoring.

Conclusions

- Most islands depend on tourism. The dilemma is that many of the related issues is a result of the development of the industry on the islands, but the bottom line is that a bad or faulty wastewater management will also be the end of this economic activity.

- The involvement of the different stakeholders is essentials given the fact that the costs are very high and must be shared, as most Governments don't have the required resources. An approach to the latter is that solutions should be sought in technologies that can be managed by local authorities that meet the environmental standards.

- Integration with physical planning is crucial and must be synchronized.

Wastewater Treatment and Disposal in the Bahamas

Christal Francis
Water & Sewerage Corporation, PO Box N-3905, Nassau, BAHAMAS
Tel: 242-323-7474 ext. 5738, Fax: 242-322-5080

Introduction

The Water and Sewerage Corporation is a quasi government organisation established under the Water and Sewerage Corporation Act (1976) with responsible for the provision of water and sewerage services in the Bahamas. The present scope of it activities encompasses water and sewerage service in New Providence and water services in several of the more populated Family Islands.

Throughout the country, the principal method of wastewater collection and disposal systems are septic tanks and pit latrines systems (90%) and the remaining ten percent (10%) are on a centralised sewerage collection systems, which including the islands of Grand Bahama and Abaco.

In New Providence approximately sixty-five percent (65%) of the total population resides on the island and only fifteen percent (15%) of the households are on a centralised collection system and the remainder on septic tank and pit latrines. The table below gives a summary of the number of service connections and the rate of growth in the sector.

DESCRIPTION	**ANNUAL COMPARISON OF TOTAL WATER AND SEWAGE CONNECTIONS FOR KEY YEARS IN NEW PROVIDENCE**					
	Units	**1977**	**1980**	**1985**	**1990**	**1996**
Sewage Connections	no.	2,720	2,842	3,131	5,008	n.a.
Water Connections	no.	22,300	23,188	26,430	28,645	n.a.

Generally, sewerage installations are conventional gravity sewer conduits in bedded trenches which run through the centre of roadways with manholes at intervals not exceeding four hundred feet (400 ft.). The sewer lines are constructed of concrete, vitrified clay and PVC pipes ranging in size from 4" to 21" in diameter. All pumping or lift stations are standardised with Flygt submersible pumps and equipment.

Plant Operations

There are six (6) main independent drainage areas in which treatment processes range from primary to secondary treatment. The six areas and the type of treatment are listed below.

Malcom Park	-	Primary treatment
Yellow Elder Gardens	-	Secondary
Eastern District – Fox Hill	-	Secondary
Pinewood Gardens	-	Secondary but not operational
Flamingo Gardens	-	Secondary but not operational
Nassau International Airport	-	Secondary but privately owned

All centralised wastewater collected is predominantly domestic in nature with an average influent concentration of 200 mg/l BOD^5 and suspended solids. The efficiency of the treatment process is to conform to the national standard of 35 mg/l BOD^5 and 30 mg/l suspended solids for disposal. Also, the final effluent is to be chlorinated to a minimum of 0.5 ppm. Final effluent disposal embraces deep well injection into wells cased to salt water (which range in depth from 250 ft. to 740ft.), or controlled recharge/recycling via drain field, lagoon or sand filter techniques. While there is no practice of wastewater disposal into surface water bodies, provision for the employment of tertiary treatment against any water contamination can be permitted on a case and facility design/performance certification basis.

All sludge from a treatment process is dried via sludge drying beds and later land filled. There is a centralised septage receiving site with both anaerobic and facultative lagoons from which the final effluent is discharged into a 250 feet deep disposal well. This lagoon system is fairly new to the Bahamas having been commissioned in June 1996. Since that time, the lagoons have not been desludged to-date.

From the perspective of wastewater fate and ultimate environmental implications, the Department of Environmental Health Services (DEHS) is the foremost regulatory agency governing the provision and performance of treatment facilities within the country. The Department has responsibility and authority to spontaneously monitor all facilities, and to act as an enforcement agent for the Water and Sewerage Corporation.

National Sewerage Development

To efficiently accomplish the task of sewage development, the government's policy for infrastructure development is enunciated in its Manifesto, which advocates environmental conservation and preservation through adequate wastes management, including expanded sewerage collection and treatment facilities. The specific requirements governing the need for sewerage collection and treatment facilities are outlined in the Bahamas Building Code and emanating policy for subdivisions. The Building Code requires a treatment plant installation at developments with a wastewater flow greater than 6,00 US gallons per day, which prompted the twenty-four (24) lot subdivision policy requiring developers to install a sewerage collection and treatment plant system.

All engineering designs of the systems, including lift stations, and material selection, are to be approved by the Water and Sewerage Corporation. All designs in part are based on an average daily flor of 50/gal/person/day. The subdivision and design policies are to foster and facilitate the provision of water and sewerage facilities to new subdivisions and private developments, which will be standardised and compatible with the public collection, treatment and disposal system both present and in future.

When private developer's complete the installation of the infrastructure, the WSC ensures that sewers are lamp tested to ensure alignment and infiltration to confirm the existence of proper gradient and pipe jointing of all individual property connection risers. It should also be noted that where there is an existing collection system, properties under new construction within 600 feet of the system are legally bound to connect to the system.

The above named practices and requirements are expected to ensure that as the rate of developments progress there would be a significant reduction of septic tanks which would also retard the rate of groundwater pollution.

Sewage Treatment and Residual Management

Despite the method of wastewater treatment utilised, the management of its residual is of utmost importance. The most common method of treatment employed in the country is secondary treatment utilising the extended aeration process with sludge treatment via sludges drying beds. Dried sludge has many beneficial uses, however, the absence of a viable market continues to preclude public orientation, promotion and acceptance.

Malcom Park is the oldest and largest drainage area which comprises the downtown commercial area with approximately 2,500 – 3,000 customer properties. Most of the sewers were replaced with vitrified clay and PVC pipes. The final collection point is at the Malcolm Park Primary Treatment Facility which was upgraded and commissioned in August 1993. The sewage is screened before lifted to the primary settling tanks and the sludge is drawn off and carried to a septage receiving site, which the effluent is discharged down a deep disposal well with a depth of 740 feet. The plant receives on average 3.0 million imperial gallons/day (MIGD).

The original sewers in the Yellow Elder Gardens/Oakes Field area were a part of the Royal Air Force Housing Development (1940). This system unfortunately was unable to be fully utilised after the subdividing and redevelopment of the properties as most of collection system were now of private properties and access to it was limited. To accommodate a governmental low cost housing project, a vacuum system was implemented in 1960 which was later converted to the conventional gravity sewers in 1989. This area encompasses approximately 10 miles of sewers with the final collection site being the Yellow Elder Gardens Treatment Facility. The plant receives approximately 0.45MIGD.

The south-eastern district is comprised of several private subdivision developments with approximately 10 miles of sewers. They have all been constructed within the past 12 years, but the system is not fully utilised due to the moderate rate of development. The flows final collection point is the Fox Hill Treatment Facility which averages about 0.4 MIGD.

Both the Pinewood and Flamingo Gardens drainage areas comprise of approximately five (5) miles of sewers each. The wastewater collected is disposed into deep wells without treatment pending the completion of the wastewater treatment facilities. The facilities treatment capacities are both 0.5 MIGD.

National Plans for Sewerage Works

Nationally, it is envisioned that subdivision development will help propagate the elimination of septic tank systems. This orientation is manifested by the on-going practice of septic tank installations at property roadside frontages to readily accommodate connection to a future centralise sewerage system on becoming available.

Conclusion

In the Bahamas, the adequate operation and maintenance of the secondary treatment plants play an integral part in the effectiveness wastewater collection, treatment and disposal. As a developing country, the interest and inclination are in the most appropriate technology for the climate and the environment, and which would especially protect the groundwater resources. Through application of the most appropriate technology, the country is committed to protecting and promoting a pristine environment so vital to the people’s health and the community’s economy.

Domestic and Industrial Wastewater Treatment Techniques in Barbados

Anthony S. Headley
Deputy Chief Environmental Engineer (ag), Environmental Engineering Division
Ministry of Health and the Environment, Culloden Farm, Culloden Road, St. Michael, Barbados
Tel: 246-436-4820/6, Fax: 246-228-7103, Email: msquared@surf.com

1.0 Introduction

At present, Barbados can be defined as a small island state whose economy is in transition. The country has sustained economic growth for the last four years, life expectancy is increasing for the population while conversely, more chronic diseases are treated in the health care system. In the environmental management field, recent studies are indicating that the ground water resources are showing signs of stress from human activity both in terms of quality and quantity. The marine water quality is deteriorating which corresponds to a reduction in the diversity and abundance of coral reef systems and fisheries resources. Generally, Barbados is experiencing the problems associated with commercial, residential, economic and political development, which mirrors previous development trends displayed by the now developed world.

Since 1992, policy makers have been engaged in constant discussions on sustainable development with a systematic, controlled approach to sustainable development policy implementation. *One of the main questions asked at discussions, which is relevant to all concerned stakeholders and Barbadians is, how can we preserve the quality of our environment for our enjoyment and the enjoyment of generations after us ?*

Right now, you are probably wondering what does this have to do with domestic and industrial wastewater treatment. However, before one can appreciate the state and urgency of wastewater treatment and the management of treatment systems, one must appreciate the historical, existing and future perspective, the relationships between social and economic trends and the impacts these activities have on environmental quality. My presentation will provide an overview on domestic and industrial wastewater treatment in Barbados, but I will try to connect this to the sustainability development concept being advocated.

2.0 Present Wastewater Treatment Methods

2.1 History of Wastewater Treatment

Barbados is a unique geological marvel of the Caribbean. Eight-five (85%) of the land mass is Pleistocene Coral Limestone underlain by oceanic or impermeable clays. The other fifteen (15%) is composed of mainly clays, shales and sandstone and is situated in an area known as the Scotland District on the north east coastline in the parishes of St. Andrew and St. Joseph. When evaluating disposal options, the geology and hydrogeological characteristic of the soils are key factors in determining the appropriate method(s) for final disposal of wastewater. Nine soil classifications have been identified and are presented in Figure 1.

Like most other countries, pit latrines were utilised for centuries as the appropriate means for the final disposal of human faeces, gray (kitchen and bath) water and storm water. In the late fifties and early sixties, studies done by Senn and Tullstrom made certain recommendations, which are still utilised to this day.

As a result of these studies, a national zoning policy for the protection of the island's ground water reserves and the control of domestic and industrial wastewater was instituted in 1963. *Table 1: The Principal Features of the Development Control Zones* provides the development restrictions for domestic and industrial wastewater control. Figure 2 provides a pictorial representation of these control zones. As you can see, the entire coastal strip is designated as control zone 5 and ironically, most tourist related developments and activities occur in this zone.

Table 1: The Principal Features of the Development Control Zones

ZONE	DEFINITION OF OUTER BOUNDARY	MAXIMUM DEPTH OF SOAKAWAY PIT	DOMESTIC CONTROLS	INDUSTRIAL CONTROLS
1	300 day travel time	None allowed	No new housing or water connections No changes to existing wastewater disposal except when water authority secures improvements	No new Industrial development
2	600 day travel time	6.5 m	Septic tank of approved design, discharged to soak away pits Separate soak away pits for toilet effluent and other domestic waste water	All Liquid Industrial wastes to be dealt with as specified by the Water Authority
3	5-6 year travel time	13 m	New premises or alterations to new existing systems must be certified by the Environmental Engineering Division (Ministry of Health and the Environment)	
4	Extended to all high lands	No Limit	No storm runoff to sewage soak away pit No new petrol or fuel oil tanks	Maximum Soak away pit for domestic waste
5		No Limit		

	Coastline		As above for domestic wastewater disposal Petrol or fuel oil tanks of approved leak proof design No restrictions on domestic wastewater disposal Petrol or fuel oil tanks of approved leak proof design No restrictions on domestic waste water disposal Siting of new fuel storage tanks subject to approval of water authority	

2.2 Package Treatment Facilities

The Public Health Engineering Division (now the Environmental Engineering Division) originally approved most private wastewater treatment facilities approximately twenty years ago in the 1970's. These facilities were traditionally installed at tourist related establishments (hotels). Today, twenty tourist related establishments have package wastewater treatment systems, while only one known agricultural and industrial establishment have installed systems to improve the quality of their wastewater prior to sub-surface discharge.

Table 2 also indicates that based on the limited monitoring efforts (quarterly sampling) by the EED, effluent discharges are consistently of a poor to average quality. Few treatment facilities meet their BOD_5 design specification, which range between 20 mg/L to 30 mg/L or comply with adopted standards for BOD_5 of 25 mg/L by the EED. Of the twenty three (23) operating treatment plants, 8.7 % produce a good quality effluent while 43.5% and 26.1 % discharge effluents of average and poor quality respectively to the environment. The effluent from twenty-one percent (21.7%) of the operating plants is not monitored. These plants will be included in the sampling scheduled for 1999.

There are several reasons why effluent quality does not meet the required design specifications and discharge standards adopted by the Ministry. The main ones include:

1. there is a high probability that operators are not fully trained to operate existing sewage treatment systems;

2. operators are not totally aware of the discharge guidelines and proposed discharge requirements;

3. wastewater treatment is not viewed as a priority by most hoteliers and hence, maintenance of most plants are secondary; and

4. the employee turn over rate is suspected to be a contributing factor. Persons originally trained to operate the plant after it was installed are no longer employed by the establishment.

2.3 Central Treatment Schemes

Currently, Barbados is constructing a 44 km sewer system capturing wastewater flows (11,300 m^3/day) within the 6 m contour on the south coast for treatment at the recently completed Graeme Hall primary treatment plant. The Master Plan for the West Coast Sewerage Treatment Facility was presented to Government in September 1998 for final review and comments prior to submission the Inter-American Development Bank for funding. The Bridgetown Sewerage System has been in operation since 1982 and serves Bridgetown the capital. Sewer lines extending from the Bridgetown Port Authority to Lower Bay Street however, connections to the sewers were not mandatory so some communities in Bridgetown are not connected to the system. This system discharges approximately two million gallons per day of treated wastewater to the marine environment through a long ocean outfall.

2.4 Wastewater Reuse

Wastewater recycling is a practice which is becoming increasingly popular amongst hoteliers. The water is mainly used for irrigation purposes in drip irrigation systems on golf courses and flower garden. No standards have been adopted for wastewater reuse but standards were developed and proposed for the West Coast Sewerage Treatment scheme.

3.0 Environmental Problems

Several problems can result from the lack of, or inadequate treatment of domestic and industrial wastewater. Of main concern is the deterioration in the quality of recreational marine water. Typical repercussions that are observed are: occasional fish kills at various surface water locations on the island, algae blooms, reduction and diversity of coral reef systems and reduction in the safety of the recreational marine water. Plans to perform epidemiological studies to further evaluate the risk factors associated with recreational water are being develop.

When considering the practice of wastewater reuse, what springs to mind is the increase potential for the transmission of water borne diseases and infections. The consequences are health and economic based being closely related to the sustainability of the tourism sector. It should be recognised that wastewater reuse increases the exposure pathways for human contact with infectious agents and micro-organisms. If not managed properly, represents a danger to the tourism sector and the fabric of the Barbadian economy.

4.0 Legislation

One of the legislative instruments C *Barbados Water Authority Act* C which governs wastewater treatment, treatment facilities and effluent disposal was drafted with the understanding that the enforcement agency would have been the Barbados Water Authority (BWA). However, the Environmental Engineering Division has adopted the regulatory role for private and public wastewater treatment systems.

The Division operates on the basis of limited legislative authority embodied in the Health Service Act, 1969. There are two main legislative tools, the Disposal of Offensive Matter 1969 and the Nuisance Regulation, 1969, which are generally used by the EED to regulate private and public wastewater treatment facilities.

A more focused legislation instrument C *the Marine Pollution Control Act* C which makes provisions for the establishment of standards and guidelines has been drafted. It is expected that this Act should be ratified by Parliament prior to year's end.

5.0 Plans for Wastewater Treatment Plants

These include:

1. implementation of the Marine Pollution Bill;
2. formation of an Environmental Standards Review and Assessment Committee (ESRAC);
3. development of environmental guidelines and standards for water pollution control;
4. operator will be required to perform mandatory analyses for key performance indicators and report to the Ministry of Health and the Environment on plant's performance; and
5. operators will require certification from a recognised academic institution accredited by the Ministry of Health and the Environment to operate a wastewater plant.

Table 3: Recommended Maximum Values For Treated Sewerage Effluent

Parameter	**Maximum Value**
BOD - 5	25 mg/ L
SS	30 mg/ L
Faecal Coliform	400/ 100 ml at point of discharge
Residual Chlorine	0.2 mg/ L

Table 4: Proposed Wastewater Reuse Criteria

Parameter	Value
Cane and Pasture Lands Treatment Criteria (mg/L) Disinfection Criteria (faecal Coliform/100 ml) Application rate (mm/yr) Location	 Secondary,<20 BOD5,<20 TSS <2,500 <800 Outside Zone 1
Golf Courses Treatment Criteria (mg/L) Disinfection Criteria (faecal Coliform/100 mL) Application rate (mm/yr)	 Tertiary < 10 BOD5,<10 TSS + N Removal <2 <800
High Rate Irrigation Treatment Criteria (mg/L) Disinfection Criteria (faecal Coliform/100 mL) Application rate (mm/yr)	 Tertiary <10 BOD5,<10 TSS, <5 T N,<5 TP <2 <2 to 3
Cash Crops	Tertiary <10 BOD5,<10 TSS + N Removal

Table 5: Proposed Wastewater Reuse Criteria

Parameter	Value
Suckwells to non-potable aquifers Treatment Criteria (mg/L) Disinfection Criteria (faecal Coliform/100mL) Application rate (m3 effluent/m2 suckwell)	 Secondary,<20 BOD5,<20 TSS + N Removal <2,500 80
Irrigation Basins Treatment Criteria (mg/L) Disinfection Criteria (faecal Coliform/100mL) Application rate (mm/yr) Suckwell configuration (L:W:D)	 Secondary,<20 BOD5,<20 TSS <2,500 20 to 300 2:2:10

West Coast Sewerage Project
Technical Memorandum No. 11 Design Criteria/Parameters
by: Standley International Group Inc.
in association with Klohn-Crippen Consultants Ltd.
and Consulting Engineers Partnership

6.0 Conclusion

Wastewater treatment has an integral role to play in the protection and preservation of environmental resources and the general health of the population. We must all play our part in ensuring the environment is safe for our generation and generations after us. However, this role doesn't stop at the installation of a wastewater treatment system. Owners, operators and responsible government agencies must recognise that this is just the first step in a process of continuous improvement. The development planning cycle for t he installation and operation of a wastewater treatment system must make provisions to include long term operational and maintenance cost and the cost to train and retain plant operators. When these vital elements are neglected for large facilities, they become significant point pollution sources. A poorly maintained and operated treatment plant is as effective as no treatment.

References

Barbados Water Resources Study Vol. I 1978
Bridgetown Sewage Re-use
Standley Associates Engineering Ltd.
Consulting Engineering Partnership Ltd.

Barbados Water Resources Study Vol. II 1978
Introduction, Summary and Master Plan
Standley Associates Engineering Ltd.
Consulting Engineering Partnership Ltd.

Feasibility Studies on Coastal Conservation
Nearshore Benthic Communities of the West and South Coast of Barbados: Importance, Impacts, Present Status and Management Recommendations
Delcan 1993

Feasibility Studies on Coastal Conservation
Terrestrial Water Quality Report
Delcan 1995

Providing A Sustainable Water Supply for Barbados
Barbados Water Authority

Groundwater Pollution Risk Assessment for the Belle Public Water Supply Catchment, Barbados
Ministry of Health-Environmental Engineering Division, Bridgetown, Barbados
PAHO/WHO, Office of the Caribbean Program Coordinator (CPC), Bridgetown, Barbados
PAHO/WHO, Pan American Center for Sanitary Engineering and Environmental Sciences (CEPIS), Lima, Peru,
British Geological Survey, Hydrogeological Group (BGS), Wallingford, Great Britain
June, 1989

Groundwater Pollution Risk Assessment for the Hampton Catchment, Barbados
Ministry of Health-Environmental Engineering Division, Bridgetown, Barbados
British Geological Survey, Hydrogeology Group (BGS), Wallingford, U.K.
Caribbean Environmental Institute (CEHI), Castries, St. Lucia
May 1991

Groundwater Pollution Risk Assessment for the Hampton Catchment, Barbados
Results of Monitoring in the Belle and Hampton catchment, 1987-1991
Ministry of Health-Environmental Engineering Division, Bridgetown, Barbados
British Geological Survey, Hydrogeology Group (BGS), Wallingford, U.K.

West Coast Sewerage Project Master Plan Report
Government of Barbados, Ministry of Public Works, Transport and Housing
Standley International Group Inc.
Klohn-Crippen Consultants Ltd.
Consulting Engineers Partnership Ltd.
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Domestic & Industrial Wastewater Treatment in Belize

Jose Mendoza
Environmental Officer, Ministry of Natural Resources & the Environment, Department of the Environment
10/12 Ambergris Avenue, Gelmopan, Cayo District, BELIZE
Tel: 501-8 22816/22542, Fax: 501-8 22862, Email: envirodept@btl.net

General Description and Overview

The land mass of Belize comprises 23,000 Km^2 (8867 m^2), located in Central America and bordered to the north by Mexico, west and south by Guatemala and east by the Caribbean Sea**.** Belize land mass includes 450 tiny islands known as cayes, totaling about 690 km^2 (266 m^2)**.** Belize has the second longest barrier reef in the world and the longest in the western hemisphere, extending 200 km (132 miles)**.** Belize has a total population of approximately 240,000 people of various ethnic backgrounds of which a great proportion live in coastal areas**.** The Belize economy is highly dependent on industries based on environmental resources: tourism, agriculture, and fisheries**.**

Approximately 57% of Belizeís territory is still under closed cover forest and some 38% of which are under some form of protected status**.** Most water resources, with the exception of some important marine habitats and spawning grounds such as mangrove habitats, remain in relatively pristine condition**.** The relative healthy condition of our environment can be attributed to several reasons**:** ***i.*** perhaps due to the relative low population density and therefore the reduced pressures on the exploitation of our resources and ***ii.*** the fact that the country has pursued an aggressive environmental resource management policy**.**

Despite all our efforts, however, the country is presently faced with threats to its water resources, these include**:** ***i.*** an increasing (solid and liquid) waste problem; ***ii.*** point and non-point source of marine pollution from land-base sources and transboundary movement of wastes that degrade the coastal zone; ***iii.*** development pressures on coastal areas and cayes due to the demand for tourism and other recreational activities**.**

Sources of Contamination:

Water bodies are the major receptacles for the disposal of liquid wastes**.** Pollution of rivers from domestic, industrial and agricultural sources is by far the largest tributary of pollutants to the marine environment**.** With the increase in tourism, the problem associated with wastewater disposal has become more acute**.** Fragile ecosystems particularly small islands are exposed to heavy pollution from sewage waste**.** In consideration of the fact that most communities depend on surface water for potable water makes water pollution the principal contamination problem facing Belize**.** Fragile ecosystems, particularly small islands, are more vulnerable to heavy pollution from sewage waste**.** Belize City and San Pedro and to a lesser extent the capital, Belmopan, are the only urban areas that are fully served by a sewerage system**.** In addition to these municipal sewerage systems, several industries have their own wastewater treatment facilities.

In Belize, the major agricultural export crops are sugar, citrus, banana and aquaculture. These agricultural crops all require the input of agrochemicals and as such contribute to some of the main non-point source of pollution. However, this paper will deal solely with domestic and industrial point sources of pollution.

1. Domestic Source:

The domestic sources of pollution are a combination of wastes from residential areas, hotels and commercial establishments. These wastes include; water from the laundry, kitchen, bathroom, etc. In the case of Belize City, about *40%* of the residents are serviced by a sewer system with the facultative lagoons for treatment and final disposal before discharging the treated effluent into the sea. The mangrove buffer between the sea and the facultative lagoons serve as further treatment of the water.

The other households and other sectors that are not serviced by the sewer system use the individual septic tank system with a soak-a-way or leach field for their wastewater treatment facility. Many people live along the flood plain and during the rainy season several rivers over flow their banks and the septic system or pit latrine becomes inundated with the wastes entering the rivers causing serious contamination affecting both the public's health and the environment.

2. Industrial Effluent:

Industrial effluent is primarily generated by the food processing industries since Belize has no heavy industry. The issue of primary concern with respect to these industries are those associated with organic loading. Some of these industries include the soft drink industry, brewery, distillery, citrus processing, sugar processing, aquaculture, poultry, dairy, meat processing among others.

Effluents from these industries have contributed to the contamination of some of our water bodies as they dispose there effluent in similar ways, either directly or indirectly into rivers and streams with little or no treatment. Some small factories utilized special designed septic tanks with leach filed to dispose there effluent. A few of the larger industries such as the sugar industry, the shrimp processing industry among others utilize facultative lagoons for primary and secondary treatment of their effluent. Several other industries are at the stage where they are currently designing and constructing adequate treatment facilities to meet the Effluent Limitation Standards since the implementation of the Department of the Environment's effluent discharge licencing programme. The establishment of new industries or factories are dealt with through the Environmental Impact Assessment (EIA) process where utmost consideration is given to ensure that clean technologies are implemented for the processing of their products and the treatment of their effluent.

Existing Water & Sewerage Systems:

1. Septic System:

The most common type of subsurface disposal system includes a septic system and a seepage pit or leaching field. The tank serves to store settled and floating solids and the leaching field serves to distribute the effluent so that it can percolate through the soil. Decomposition of organics takes place under anaerobic condition. A buried septic tank is used to provide the necessary primary treatment step, as well as to act as a sludge storage tank. To ensure proper operation and a long service life, septic tanks should be pumped clean on a regular basis every few years. Only sealed septic tanks to prevent leakage are currently being approved. The use of septic tanks is recommended primarily in those areas outside the sewerage system service area and where the permeability of the soil allows for the proper functioning of the tanks and leach field. In addition, housing projects are being required to install low flush toilets to minimize the volume of water.

2. Facultative Lagoons:

The *Belize City Water System* currently includes a 3.0 million U.S. gallons per day (USGD) water treatment plant on the Belize river. The sewerage system in Belize City serves about 40% of the population of Belize City. It consists of conventional gravity sewers in 15 zones where sewage is collected at a central pumping station and pumped to a neighbouring zone towards the treatment works. Treatment is provided by a 2 two-cell facultative sewage lagoons located on the south side of Belize City. The lagoon cells operate in parallel and each is designed to provide 10 days hydraulic retention time. Currently, plans are underway to expand this facility with two additional cells. Treated effluent is discharged into Sibun Bight through a canal that runs through the mangrove wetland in which the lagoons are located. San Pedro Ambergris Caye sewage treatment system consists of three facultative lagoons with impermeable layers at the bottom (unlike Belize Cityís system). It has a capacity of 600,000 g.p.d. After treatment, the unchlorinated effluent is discharged into the surrounding mangroves for polishing before entering the surrounding water. There are plans to expand the service area and treatment capacity, in the near future, in areas that are not serviced by the sewer system.

3. Biogas:

The technology currently being advocated for sewage management for small islands is toilets fitted with composting or biogas tanks. There is considerable experience with biogas tanks which are being tested and promoted by the Biogas Unit of the Ministry of Agriculture. In 1993 a $5m^3$ digester to treat human waste was constructed at Central Farm quarters. The result obtained have been very promising as shown by water tests conducted by the Health Department at the Belize City Lab. The results have shown that the Biogas plant works better in preventing contamination than a septic tank. Construction costs were also lower for the biogas plant than the traditional septic tanks. Biogas plants have also been used successfully in Belize to treat pig and cattle manure. Advantages which have been observed with the use of these plants for human waste treatment compared to latrines are***:***

- construction can be done in any soil type clay soils as well as sandy soils;
- This plant can be constructed even in areas where water is scarce since these do not need much water;
- improved sanitation control, compared to pit latrines, and can be built for communities as well as for individuals to prevent nightsoil dumping into the sea or nearby streams and rivers;
- end product can be used as fertilizer for ornamental and fruit trees;
- a soak away or a fertilizer pit may be constructed at the over flow;
- biogas may by used instead of compressed gas in remote areas;
- use of organic and inexpensive fertilizer could be used to landscape areas for prevention of erosion;
- the anaerobic process kill and/or controls pathogens by fermentation inside the digester.

Currently, there are a total of 31 biogas plants in Belize. However, these plants have all been constructed on the mainland where the watertable is high. The success on the islands has not been tested. However, there are plans to test the effectiveness in preventing pollution on the islands. Permission has been granted, through the EIA process, to establish the biogas system to be used at a resort in Nicholas Caye, a small island in southern Belize.

Alternating Intermittent Recirculating Reactor (AIRR System):

The AIRR system is an innovative alternative for the conventional *drain field***.** It is designed to treat effluent in areas where percolation is limited or non-existent so the land can still be used for homes or business. Its biological process is natures way of clearing up waste water. This system creates colonies of different types of bacteria, they are cannibalistic in nature, and eat or destroy each other, the results is clear water. This clear water is ready for reuse in above ground irrigation discharge into waterways or to drain underground.

This system is presently being used in Hunting Caye, the largest of the six cayes of the Sapodilla Cayes located in the south and has approximate area of six hectares. This system is also recommended for other islands especially those with high tourism potential.

Fiberglass Septic Tanks:

Apart from the traditional two or three chamber concrete septic tanks, the use of fiberglass tanks is becoming more widely used in the country. The fiberglass septic tanks consists of multiple layers of glass fiber material that has been saturated with a corrosion resistant resin. This results in a fiberglass laminate that is much stronger and more rigid than non-laminated plastics. The strength, pound for pound, is even greater than steel. It is believed to be 100% water tight, corrosion resistant, lightweight and excellent for high ground water application. These tanks are currently being encouraged for karst topography areas such as the northern areas and low lying area of Belize where the water table is high.

Wetland System:

Only one resort, located on the southern coastal area of Belize is using the Wetland Wastewater Treatment facility. This system is considered to be an ecological wastewater treatment system. It is believed to be a 100% ecological system, anaerobic - aerobic with two components;

1. a watertight, underground tank for settling out solids and commencing microbial decomposition (anaerobic); and

2. a cement-lined surfaced flow, created wetland with both floating and emergent (soil rooted) wetland vegetation.

The basic principle is the biological mechanism of contaminants removal, including;

- Physical sedimentation: anaerobic process in septic tank. It removes - coliform, nitrates, organic phosphates, bacteria and virus.

- Filtration: particles are filtered by passing through water substrates and the roots of the plants. It removes - sedimented solids and colloidal solids.

- Absorption: absorption though substrates, plant roots and by force of particle attraction. It removes - colloidal solids, phosphates, heavy metals, nitrogen and refractory organism.

- Chemical Precipitation: formation of coprecipitation of products with insoluble components. It Removes - phosphates and heavy metals.

Some of the benefits using this system include:

- low cost, low energy or no energy process requiring minimal operation attention;
- reliable and cost effective treatment;
- high level of effective treatment and contaminant removal;

- lack of odours, mosquitoes and other insect vectors;
- minimal cost of operation and maintenance system;
- ornamental function by the addition of flowers and plants, green areas and integration in the landscape.

Currently, the above mentioned wastewater treatment systems are presently being utilized in Belize for a variety of domestic, commercial and industrial effluent treatment**.** With the enactment of the Environmental Protection Act (EPA) and its subsequent regulations - the Effluent Limitation Regulations and the EIA Regulations all new and existing industries must employ environmentally sound systems to treat their waste water in order to protect the public's health and to ensure a safer, cleaner and healthier environment**.**

Good wastewater and sewage disposal and treatment is important for the protection of the environment, to promote good public health and to protect the tourism industry itself**.** Whatever system a household, community or industry utilizes it must be designed and maintained properly to ensure that it works the way it was intended and to maintained its integrity to ensure the protection of the environment and the public's health**.** As time goes by, new and improved environmentally friendly systems must be developed and promoted at **reasonable cost** to all sectors**.**

References:

Alterating Intermittent Recirculating Reactor (AIRR System). SPEC Industries, Inc.

Arthur B. Archer, Consultant, Land-based Sources of Marine Pollution Inventories. UNEP Regional Coordinating Unit. Countries: Belize, Cayman Islands. May 1994

Cross E. William. Environmental Assessment of the Proposed Water & Sewerage Expansion, Belize City, Belize. June 1995

Ecological Subsurface Flow Constructed Wetlands Systems for Wastewater Treatment. Planetary Coral Reef Foundation.

Fiberglass Tanks for Water and Waste Water Collection and Process Systems, Submittal Documentation. Fiberglass Solutions International.

Health and Environment, A National Plan for Health and Environment in Sustainable Human Development. Belize, August 1997

Adopting, Applying and Operating Environmentally Sound Technologies for Domestic and Industrial Wastewater Treatment in the British Virgin Islands

Mr. Mukesh Ganesh
Engineer, Water & Sewage Department, Min. of Communications & Works
PO Box 130, Roadtown, Tortola, BRITISH VIRGIN ISLANDS
Tel: 284-494-3416/7 ext. 5797, Fax: 284-494-6746, Email: water@caribsurf.com

1 Introduction

The British Virgin Islands (BVI) is made up of about fifty small islands located in the Lesser Antilles in the Caribbean Sea. The largest island, Tortola, is only twenty-four square miles in area with it's capital Road Town. Other islands that have some significant population includes Virgin Gorda, Jost Van Dyke and Anegada. Public water supply is only available in Tortola and Virgin Gorda and two separate sewerage systems are in Tortola. The BVI has a current population of 19,482.

Sewage disposal in the British Virgin Islands has classically been by either direct dumping in the ocean or by the use of septic tanks and soak away or field beds. The direct discharge of raw sewage to the ocean is practiced in the BVI by residences and businesses along shorefronts and by yachts anchoring in the many harbours and bays. In these areas where swimming, snorkelling and scuba diving are tourist pastimes, direct discharge of raw sewage to the sea is not entirely appropriate. In the capital, Road Town, sewage is collected by gravity sewers and channelled to wells from where it is pumped into the ocean. Intermittent disinfection of the wells is carried out.

In many other areas, there have been ongoing complaints of flows of septic tank effluent across public thoroughfares and into neighbouring properties. In the BVI, there are few, if any, areas where simple land disposal of sewage would be practical, in part due to the shallow depth of topsoil throughout the islands. Recently the first public sewage treatment plant with capacity of treating 45,000 gallons per day has been commissioned to serve Cane Garden Bay in Tortola. This plant is a sequencing batch reactor (SBR) with three parallel tanks. In Anegada pit latrines are used in addition to water closet facilities and these are now contaminating the few water wells the residents are using to obtain their fresh water supplies. Anegada is a flat island made up of coral limestone and it is difficult to construct septic tanks and pits for latrines.

The nature of the sewage generated in the BVI is mostly of a domestic nature. Laundromats produce most of the industrial waste. There is no major manufacturing industry in the territory.

2 Options of Technologies Available

Sewage can be treated to various extents and by a variety of different methods prior to disposal. These range from a total lack of treatment to full biological treatment with tertiary treatment for disinfection. Some options of technologies available are:-

- disposal of untreated sewage,
- septic tank and on site disposal,
- chlorination and disposal of sewage,
- primary treatment mainly by settling in clarifiers or sedimentation basins,
- secondary treatment. Some of the more commonly used biological processes are:-

    - activated sludge process including the sequencing batchreactor,
    - attached growth biological processes (e.g. biodisccontactors and trickling filters),
    - aerated lagoons,
    - stabilisation / oxidation ponds.
    - tertiary treatment,
    - combinations of the above, i.e., primary plus tertiary.

Other high tech systems for complete treatment of the effluent and sludge may be available but may not be affordable in the circumstances.

3 Proposed Treatment

The economy of the BVI is very dependent on tourism and it is the duty of the Government to ensure that the environment is kept clean so that more tourists can be attracted.

In the BVI the sewage will have to be treated to some extent to ensure that the disposal of effluent into the surface waters or the ocean does not adversely affect the ecosystem. Suitable available land space is limited so any treatment proposed would eliminate treatment processes such as stabilisation ponds, which take up a relatively large surface area.

4 Monitoring

Fecal colifor bacteria, an indicator of pollution caused by the presence of human waste, have been monitored. Currently the Department of Conservation and Fisheries monitors the coastal waters of the BVI. A 1988 report by Dillon Consulting Engineers of Canada referred to a monitoring programme that identified Road Town and Cane Garden Bay as being the most polluted areas in the territory. Government has since installed the treatment plant at Cane Garden Bay and is formulating plans for treating sewage in the Road Town area. Since the installation of the sequencing batch reactor at Cane Garden Bay, no results have been released from that area.

At the present time, yachts in the BVI do not require holding tanks for sanitary waste. The practice which always has been followed is to permit direct dumping of sewage from yachts whether at anchor or at sea. At Cane Garden Bay a yacht pump out facility has been constructed and requires constant monitoring for it’s effective operation.

5 Future Directions

The Government of the British Virgin Islands has an extensive plan to improve sewage collection and disposal in the territory. Besides the new system that was commissioned in Cane Garden Bay in August 1998, the following new works are planned:-

- design and construction of a new sewage collection and treatment system for the eastern end of Tortola. Here the treated effluent would be available for use as irrigation at the nearby Agricultural Station, which uses expensive potable water for irrigation presently. Also the treatment plant will help to eliminate the evidence of contamination arising from sewage discharge into the ocean along the total length of the East End settlement. The sewage generated from the planned expansion of the airport at Beef Island will be treated at this plant.

- design a construction of a new sewage treatment plant in the vicinity of Road Town to treat the sewage before disposing the effluent to sea. Minimal modifications will be needed on the existing sewer system and secondary treatment would eliminate problems of contamination. The possibility of water conservation and reuse hinges on the existence of an adequate treatment system.

- design and construction of a new sewage collection and treatment system for the Valley, Virgin Gorda.

Any system that is designed to operate in the BVI has to take into consideration that the islands lying in the hurricane belt. Recent experience has shown that the SBR at Cane Garden Bay operated well during hurricane Georges.

6 Conclusions

The following have to be taken into account to adopt, apply and operate environmentally sound technologies for domestic and industrial wastewater treatment in the BVI.

- the primary concern is to produce an effluent that will not adversely affect the environment especially in the contamination of the many beaches and harbours around the territory. The technology selected may need to cater for tertiary treatment, thus a high quality of effluent.
- desalinated water is supplied for public’s use and is quite expensive and with tertiary treatment of the effluent there is the possibility of recycling the water for domestic consumption or at least used for irrigation purposes.
- the disposal of sludge is also of paramount importance and the Government is now making initial preparations to have a suitable area designated for the construction of a drying bed. Septage from septic tanks and sludge from waste water treatment plants should be dried and can be used as a soil conditioner in agriculture.

- that septic tanks with soak away are not an effective means of wastewater treatment and disposal in the BVI because the top soil is too thin for effective biological breakdown of the effluent.
- the importance of monitoring cannot be over emphasised. More detailed tests for coliforms and nutrients should be carried out at more locations. The Ministry of Natural Resources and Labour, Department of Conservation and Fisheries are doing these tests.
- legislation should be enacted to force yachts to be retro fitted with holding tanks for waste which should be discharged at approved locations where the sewage can be conveyed to a waste water treatment plant. In addition, steps should be taken immediately to limit overnight mooring of yachts to those that have holding tanks.

Domestic Wastewater Treatment in Colombia

Dr Cruz Fierro
Direccion Tecnica de Desarrollo Sostenible. Ministerio del Medio Ambiente, Calle 37 No. 8-40
Santafe de Bogota, COLOMBIA
Tel: 47-1 338-4900 ext. 430-429, Fax: 47-1 288-9725, Email: cruzser@hotmail.com

Introduction

This document presents a partial vision on the state of the treatment of residual waters in Colombia. This paper will focus on the municipal wastewater treatment, due mainly to the fact that the information on the treatment systems used by industry is dispersed in different regional entities (34 regional environmental authorities - CAR¥s) which have the competence and attribution to determine the characteristics of the wastewaters to be disposed and the type of treatment technology that it must install by industry, this is done depending on the environmental characteristics on each zone where it is located each type of industry.

Opposite to the information about treatment systems used by industry, the information on the treatments of the domestic wastewaters is more aggregated and centralised, due to the fact that the treatment of these waters is in charge by Pubic and/or Private Own Treatment Work Systems (POTWS) under the control by Governmental Entity.

State of Wastewater Treatment

The promulgation of the decree 1594 in 1984 mandates that any company that disposes any effluent into any water body, it has to treat these waters to meet certain legal environmental quality requirements before to be disposed.

This legislation led the industrial companies to the implementation of some type of waste water treatment, so this caused that up to now the majority of formal industry of the country haven treatment systems. With respect to type of installed technology exists a high variety that fundamentally depends on aspects as the type of industry, its size and the obligations imposed by the CAR.

With respect to the urban centres, the above decree requests that their wastewaters to be treated, this has not been accomplished and today the most used method for the disposal of the municipal wastewaters in the rivers does not include any previous treatment.

Only during the last 5 years, the four more important urban centres of the country (with more than one million of people) have begun to construct wastewater treatment systems. For example, the city of Bogota with almost 6 million of people will have and the end of 1999 a primary wastewater treatment system that will treat the water generated by approximately two million of inhabitants and it is foreseen to have a water treatment for all the population by the year 2020, though it exists uncertainty on the future financing of this project .

The current situation of Colombia related to its domestic wastewater treatment is that 10% of the municipalities make some type of treatment of their waters, with an extent of the 16% of the population of country. Now it exists a series of projects underway to provide treatment plants to other 112 municipalities so about 3.5 million of persons will be benefited through this service. To this it is expected that 20% of municipalities have their own treatment systems.

The most majority of these municipalities have adopted the type of treatment called estabilization ponds, and in a low proportion systems as trickling filters and activated sludge.

Though in the country had been installed technologies a long time ago as the UASB (Bucaramanga), the open economic model established in the country in the years 90, permitted the existence in the market of a great variety of technological offers that cover the great majority technological options offered all over the world today.

The market trends indicate that the technological options are the following:

For the urban centres segment with population until of 20000 inhabitants, it is offered compact plants generally based on some type of aerobic system.

For cities with more inhabitants it is offered the construction of treatment systems using generally technologies as trickling filters or activated sludge, using stabilisation ponds as final treatment.

The problem of the way of providing this type of technologies is that small cities have acquired or they can acquire them that have a high operation and maintenance cost and with the limited budget of these cities cause that these plants work at very low efficiency levels and in some cases they are not operated or they are abandoned.

With respect to technologies for domestic and industrial wastewaters treatment, it is a policy of the Ministry of the Environment not to recommend any treatment technology, since it considers that its responsibility is to establish the parameters of quality of the water bodies and the characteristics that it must fulfil a wastewater to be disposed and to the enforcement of its compliance, in this way each company is free of choosing between the existing technological offers that most fit its necessity and the work of the environmental authorities is to check that with the technological option acquired meets the existing law requirements for disposing and monitoring its compliance.

With respect to the future of the wastewaters treatment in Colombia, it presents the following two features:

Related to industrial residual waters, the government issued the production cleaner policy in which it is established between other objectives, the prevention and to minimisation the generation of polluted charges ,from this point of view, it is pursued to go from the treatment vision end of the pipe to the control in the source, because it is considered that with this strategy can be achieved in a better way the decrease goals of the pollution generated by industry and the reduction of dangers of the substances disposed.

With respect to the domestic wastewaters of urban centres which represent in many places a great source of pollution of rivers, the government has designed a plan that includes; a) Priority zones to construct treatment systems; b) an assessment of the efficiency of the existing systems; and; c) the creation of regional financial funds for of the construction of these systems.

Additionally, with the implementation of the pollution charges, as an economic instrument to improve conscious to invest in pollution control. It is expected that the CARs play an important role for the technical and financial assistance in the construction of treatment plant for the cities.

Updated Inventory of Localized and Non-Localized Pollution Sources, Including Industrial, Domestic, Human Development and Port Wastes, Furnishing Specific Alternatives as to How to Deal With Them.

José Miguel Ramírez Corrales
Costa Rica

Introduction

In the frame of GEF RLA/93/G41 Regional Project, the present study, which includes "Updated inventory of localized and non-localized pollution sources, including industrial, domestic, human development and port wastes, furnishing specific alternatives as to how to deal with them" is thus established as integrating part of it at the short, middle and long terms and it is about this issue that this paper has been developed.

In Costa Rica, the marine environment of Port Limon and adjoining coastline has been affected by both natural and man-caused polluting mechanisms. For instance, both deforestation and natural disasters have caused severe soil erosion and the dragging by streams of enormous amounts of different sediments which have been deposited at the Caribbean shorelines. Additionally, poor disposal of solid waste, the dumping of untreated waste water outlets from the city, as well as industrial waste water and litter coming from boats and ships, are all factors that affect the marine ecosystem and debase the natural coastline beauty. The pollution at this shoreline has grown due to the weakness of enforcing mechanisms and administrative systems that have to do with urban planning, industrial growth and proper soil use (soil-use capacity).

The specific objective of this study was to carry out updated inventories of localized and diffuse pollution sources of the marine and coastal environment of Port Limón, Costa Rica, and adjoining areas, including industrial and agricultural discharges, domestic waste water outlets, port and urban development waste, along with specific alternatives as to how to deal with them in the short, intermediate and long terms. The present study is focused on the area located between Moin and Limon's airport. This is the area where both pollution and different human activities are most concentrated along Costa Rica's Caribbean coastline which is 212 k. (133 miles) long. The area of influence in this inventory comprises Limón centre which has 84125 inhabitants (as of 1988). The total area of this province is of 9188 km^2 (3590 $miles^2$). The area in the inventory has 1766 km^2.

The following have been identified as the main pollution sources that add to the negative environmental effect upon Port Limon's sea water:

- Domestic waste water from urban areas which are dumped with no previous treatment directly to the shoreline or through receiving streams (or creeks) in the area.
- Solid waste from urban areas and the Hospital .
- Only about half of the garbage is collected to be delivered to the municipal dumping ground, due to the fact that local municipal and port authorities lack ability to enforce existing laws.

- Agrochemicals (fertilizers and pesticides) coming from the agricultural area found North of the study area.
- Hydrocarbons from National Petroleum Refinery, RECOPE, fishing boats and cargo ships.
- The polluting load coming from the middle and upper basins of the rivers that flow into the ocean along this shoreline, as well as sediments from agricultural and urban areas.
- Industrial dumpings and outlets.
- Port facilities and their activity.

Main Results

It has been possible with this consultorship, during the time span between August 1996 and June 1997, to identify and set priorities as to the main pollution problems to be found at the region of study, based on the reviewing of the existing information about the inventory of localized and non - localized pollution sources, which are herewith detailed.

The lack of an adequate landfill and proper management of different types of solid waste, as well as the pressing need for an efficient disposal system of hospital waste, constitute the region's main environmental problem, a short-term solution to which must be provided.

As far as untreated sewage waters which are dumped along the shoreline, I.C.A.A. (National Institute of Aqueducts and Sewage Systems) has undertaken the refurbishing of 40% of the sewage system network. Additionally, initial studies are being carried out as to the laying out of an underwater discharge outlet of domestic waste water 700 m. (2300 ft.) away from the coast. The main sewage discharge of the Vargas Park main sewer shows typical levels of raw waters with B.O.D. over 200 mg./L, oils and greases at 306 mg./L, phosphorus at 2.7 mg./L and total nitrogen at 25 mg./L.

The discharge of untreated sewage waters off the shoreline which have been detected in the study, has forced to declare certain beach areas as forbidden for public use, as for instance the Municipal Swimming area of Port Limon, showing levels of 35100 bacteria per 100 ml.

In the area of the lower basin of the Limoncito river, there are certain industrial plants such as ENVACO (Industrial Packagings of Costa Rica) and DECAR (Cardboard Dept. of Standard Fruit Co.), which have low-efficiency waste treatment systems that are not able to furnish proper discharge quality of the final effluent. Thus, for instance, ENVACO's discharge outlet #2 in the first monitoring campaign showed a pH of 9.47, B.O.D. of 4980 and C.O.D. of 12680 mg./L. At the second stage, the monitored levels were 10.45 for pH, B.O.D. of 51000 mg./L and C.O.D. of 76400 mg./L.

ENVACO's discharge outlet #2, represents the outlet of a wastewater treatment plant and shows a pH of 10.1 and 10.45 in both monitoring campaigns. In DECAR's case, the treated effluent's discharge has a pH of 5.45, a B.O.D. level between 588 and 690 mg./L and a C.O.D. level between 918 and 1129 mg./L. These levels do not comply with the quality standards required by local legislation.

Other industrial plants such as Coca Cola discharge wastewaters directly to the environment onto receiving streams, showing pH levels of 11.77 and 11.85, B.O.D. between 1707 and 8770 mg./L in outlet #1 and between 590 and 3055 mg./L in outlet #2, as well as C.O.D. levels from 3640 to 12850 mg./L for outlet #1 and 1055 to 4500 mg./L for outlet #2.

The banana plantation activity basically furnishes organic solid waste such as the pinzote (banana rackies), fruits that have been rejected for market and plastic bags used to envelop the banana bunches. To a certain degree, this activity also adds to the sedimentation produced downstream caused by some drainage systems that don't consider soil - protection measures. Despite that, there are certain plantations such as DOLE's La Paz, which set an example as far as the management of banana rackies, plastic waste and leftover bananas. Wastewaters from DOLE's La Paz processing plant showed B.O.D. levels from 18 to 22 mg/L and C.O.D. from 40 to 82 mg/L.

The concentration of hydrocarbons in coastal waters show very low pollution levels, from 1.00 to 1.85 ug/L in 3 samples that were analyzed, which is much lower than UNESCO standard of 10 ug/L of crisene. This fact reflects the excellent treatment conditions of RECOPE's (National Petroleum Refinery) facilities.

The diffuse or non-localized pollution, due to the seaport activity of large ships and small boats along the shoreline is mainly caused by the latter, since the larger ships follow the International Maritime Organization's recommendations and discharge beyond 10 nautical miles from shore.

The dragging of sediments caused by deforestation and other natural phenomenae in the region, is the main source of pollution of coastal waters on coral reefs. It is believed that along with the sediments, the pesticides used in agricultural activities in the region, are also dragged along.

From a hydrographic and oceanographic point of view, the information consulted as to the dispersion of pollutants in the coastal environment is scarce, incomplete and is not up-to-date, so that it doesn't allow a proper quantitative nor qualitative analysis about the possible pathways of pollutants along Limon's shoreline and adjoining areas, nor as to which would be their probable direction followed once moving away from the port.

It is important to point out that besides the above-mentioned pollution problems, the region of Limon was affected by an (7.4 Richter scale) earthquake in 1991 which destroyed previously existing city's drainage system, additionally affecting the sea bottom level (which rose 1.5 m. or 5 ft.), thus making it necessary to dredge the port facilities area. April 1991's earthquake, caused an uplifting of the sea bottom, leaving coral reefs and domestic waste water outlets totally exposed. This caused Portete beach to disappear and the death of 5% of the region's coral reefs.

Main Priorities to Control and Minimize the Pollution

This study identifies the following priorities so as to control and minimize the pollution of shoreline waters at the short and intermediate term:

- The need to carry out technical and economical studies for the placement and functioning of a proper landfill for domestic and hospital waste. The possibility of using the region's railway infrastructure is recommended.
- The implementation of gathering sites for the recycling and reusing of waste materials, including used lubricant oils.
- To initiate hydrographic and oceanographic studies which would support the adequacy of the underwater outlet's discharge site. Necessary studies for this purpose would be: a) Measurements of marine currents with the aid of a network of current-measuring devices. Updating of region's climatology. Tide measurements with the aid of a tide-measuring device. Batimetrical map lay-out at a 1:2000 scale of the shoreline zone, especially of proposed area for placing waste water discharge outlet.
- To carry out technical and economical studies regarding the possibility of building a joint industrial waste water treatment plant that would look after the needs of the industrial plants found at Limoncito river's lower basin.
- To propose implementing an environmental assessment so as to study occupational health hazards at banana plantations.
- Information about pesticides in water suggests that forthcoming studies should focus on the sediments dragged by streams and their effects on living organisms and not necessarily on the water itself.
- To speed up environmental impact study, design and construction of underwater waste water discharge outlet, with the purpose of diminishing fecal pollution of beach waters.
- To inform potential swimmers of danger involved in bathing at Piuta and Municipal Swimming beaches.

It is crucial for marine and coastal resources to be sustainable in order for the region's biodiversity and human health to be protected while enhancing its economic development. At a regional level, the part to be put into practice with this work, along with the rest of the major study's sections and selected areas, will contribute to the protection of international ocean waters and will allow the minimization of forthcoming environmental impact cases that would hinder development and economical activities, through institutional strenghthening and the enhancement of international cooperation.

Cuba: Technologies For Wastewater Treatment and Disposal - Current Status and Performance

Eng. Carmen C. Terry Berro
Senior Specialist, Environmental Agency, Ministry of Science, Technology and Environment
Calle 20 Esquina 18A, No. 4110, Playa, Ciudad de la Habana, CUBA
Tel: 537-229351/296014, Fax: 537-249031, Email: cterry@cigea.unepnet.inf.cu

Introduction

Among the highest priorities established in Cuba's Environmental Strategy, the application of environmentally sound technologies for wastewater treatment and disposal is receiving special attention, taking into consideration that the inadequate liquid waste management has been identified as one of the most significant shortcomings in the country's environmental work during the present decade.

The National Inventory of Point Sources of Pollution reveals that 42% of the identified sources are human settlements and social facilities, while 33% and 25% are industries and livestock facilities, respectively. Only 54% of these polluting sources have some wastewater treatment system; the remaining percentage discharges their untreated wastewaters to inland and marine waters.

To achieve the goal of gradual decrease of the polluting loadings disposed of to the environment, a diagnosis of the situation of wastewater treatment and disposal has been made, including basic information on the current status of the technologies used for this purpose and the perspectives of improving their choice, application and performance.

Municipal Wastewater Treatment and Disposal Systems

In 1997, 90.4% of the Cuban population had access to sanitation services, provided by sewerage systems (34.2%), septic tanks and latrines (56.2%). It has been estimated that only 17% of wastewater collected by urban sewerage received some treatment last year.

A narrow range of technologies is being used in our country to treat domestic wastewaters and dispose of the effluents. These technologies can be grouped as follows:

- Five conventional trickling filter (rock-filled filter) plants in critical situation due to equipment failures, the lack of maintenance and spare parts and operating problems. Only one is functioning, providing primary treatment. The remaining plants are out of operation.

- Around 1 250 stabilization ponds distributed throughout the national territory. Most of the systems consist of one facultative cell. Although this type of technology is considered an appropriate option for our country's conditions, many existing systems don't have an efficient functioning because of design problems, hydraulic and organic overloading, starting up problems and the lack of maintenance.

- On-site treatment and disposal systems for wastewaters coming from small communities, individual dwellings and other facilities. The most typical system consists of a grease interceptor tank as pretreatment and a septic tank followed by a soil absorption field for final treatment and disposal. When soil disposal can't be used, the most common alternative is septic tank in conjunction with granular-medium filters (downflow or upflow type) and effluent discharge to surface waters.

- Improper design and the limited capacity of the operating companies to meet the cleaning schedules of septic tanks, are factors that have influence in the poor performance of these technologies. In many settlements, latrine seepage percolates down and reaches groundwater used for human consumption.

- A few package plants in tourist zones based on activated sludge processes, that provide treatment to wastewaters from hotels. Some of these plants treat wastewater to tertiary level to reuse effluents for irrigation of lawns and gardens. They were recently built and in general, their performance is satisfactory.

Industrial and Livestock Wastewater Treatment and Disposal

Industries located in cities with sewerage coverage, usually discharge their liquid wastes with no pretreatment into municipal collection systems. Others, only provide partial treatment prior to discharge into receiving waters.

Facultative and anaerobic ponds with aerobic cells as a final process to polish the effluent before discharge, are widely used to treat livestock wastewater, as well as those industrial wastewaters in which organic matter predominates. Around 500 ponds have been constructed in Cuba for this purpose.

Our main economic activity, the cane sugar industry, requires special attention because of the magnitude of the environmental damage that its facilities can cause. At present, wastewaters coming from sugar mills are being used for the fertilized irrigation of the sugar cane plantations. A great effort is being made to extend this practice to the totality of these facilities with proper conditions to assimilate this technology.

Positive results have been achieved by using it; in addition to the substantial mitigation of environmental pollution and the decrease of the cost of wastewater treatment facilities, agriculture yield and sugar production have increased in the irrigated areas.

To avoid long-term affectations to the soils, internal measures are taken in the production process, mainly the segregation, recollection and reutilization of the acids and alkalis used in the cleaning of the technological equipment and the poured petroleum products.

The most common wastewater treatment technologies used in the major productive activities are summarized in the following table.

SECTOR	MOST COMMON TECHNOLOGIES
Sugar industry	Grease and oil interceptor tanks Stabilization ponds in series Fertilized irrigation
Cannery	Stabilization ponds in series
Fishing industry	Oxidation ditch process
Food and beverage industry	Stabilization ponds in series
Biotechnology	Anaerobic digestion +sterilization Stabilization ponds
Coffee production	Stabilization ponds
Chemical and metallurgical industries	Physical-chemical process (equalization, neutralization, precipitation, flocculation, sedimentation, etc.).
Oil production	Oil -water separation Deep well injection
Pesticide factories	Evaporation lagoons
Livestock facilities	Anaerobic digestion Stabilization ponds in series

In general, the situation of the industrial and livestock wastewater treatment systems, regarding technical conditions, operation, maintenance and performance is similar to that one of the treatment facilities for domestic wastewater.

Future Directions

Taking into account the country's peculiarities and economic reality, the characteristics of the major sources of pollution and the current status of technology for wastewater treatment and disposal, emphasis will be placed on the following actions:

- Adoption of technology suitable for local people and local conditions, specially low-cost technology.
- Introduction of technologies that provide effluents that meet the quality requirements for reuse in irrigation, unicellular protein production, aquaculture and other non-potable uses, particularly in sugar industry and livestock sector.
- Introduction of dry collection methods of solid and semisolid wastes in livestock facilities and some industries, to avoid or decrease their presence in wastewater discharges.

- Introduction of anaerobic treatment technology followed by a polishing process in some types of industries and livestock sector, as an appropriate way to reach acceptable pollutant removal efficiency and obtain biogas to generate energy.
- Gradual introduction of constructed wetlands and aquatic plant treatment systems in small communities, to assess their performance in Cuba's conditions.
- Achievement of a more efficient and effective functioning and maintenance of the existing wastewater treatment facilities and progressive rehabilitation of those in defficient technical and physical conditions.
- Systematic control over the operation and maintenance of the installations.
- Training of personnel in charge of the facilities' management and operation.

Conclusions

The application of environmentally sound technologies for wastewater treatment and disposal is essential to halt and reverse the effects of the environmental pollution caused by the inadequate management of domestic, industrial and livestock wastewaters.

At present, the Cuban economy can't by itself cope with the demand for material and financial resources to maintain and repair the existing infrastructure and significantly increase wastewater treatment coverage. Consequently, the country requires international cooperation.

Although our country has the potential technical capacity and the social infrastructure to generate and receive environmentally sound technologies for wastewater treatment and disposal, organizational and management efforts must be made to overcome the existing shortcomings in waste management, including the effective implementation of instruments such as the environmental legislation and standardization, the Environmental Impact Assessment as a tool for evaluating the technologies to be used in the new development projects, the Environmental Licensing Process, the State Environmental Inspection and the Scientific and Technological Innovation.

References

Ministry of Science, Technology and Environment. National Environmental Strategy, 1997.

PHO/WHO. Sectoral Analysis in Water Supply and Sanitation in Cuba. Sectoral Analysis Series No. 3, 1994.

Center for Environmental Information, Management and Education. National Inventory of Point Sources of Pollution, 1998.

Acosta R. Clean Technologies: Cuban Experiences. Industry and Environment/UNEP, Vol. 12, No.1, 1989.

Adopting, Applying and Operating Environmentally Sound Technologies for Domestic and Industrial Wastewater Treatment

Wastewater Disposal in Haiti

Prof. Carlo Lafond
Directeur General, Ministere de L'Environnenment, 181 Haut Turgeau, P-AU-P, HAITI
Tel: 509-45 0645/45 7585/45 7572, Fax: 509-45 7360/45 1022,
Email: deg.mde@rehred.haiti.net, Email: deg.mde@palaishaiti.net

As way of introducing this topic of Wastewater Disposal in Haiti, we should emphasize that, in order to choose the appropriate system in a country like Haiti, technical, social as well as economic or political considerations have to be made:

- Public health considerations have to take into account not only the individual systems of the private houses, but the public places, like market places, schools.
- Public participation in all phases of the project, design construction and maintenance. Once the collective contribution of a community is guaranteed, institutional arrangements have to be setup for the sustainability of the project.
- Environmental quality criteria, taking into consideration the viability and all the possible impacts of the project on the groundwater and on the air.
- In Haiti, the economic considerations involve the lowest dependence on imported products like sinks and W.C. toilet bowls, and even the maintenance tools of cleaning trucks equipped with vacuum pumps.

Wastewater Disposal Systems in Haiti

Basically two possibilities exist as wastewater disposal in Haiti:

- Either the collective disposal through small sewer systems including a primary treatment plant.
- Or the private disposal system through individual holding tanks, cesspools and septic tanks.
- Technically speaking, sanitary sewer system by gravity or under pressure would represent the best available technology for Haiti, and such a system could be used in the brand new rich suburban neighborhoods.

Two historical cases come to mind:

i. In 1972, a complete system of sanitary sewers, separate from stormwater sewers, was designed by the American firm called Engineering Science Inc., but finally the idea of a separate sanitary sewer system was abandoned.

ii. And, as a matter of fact, a recent upper - middle class community named BELVIL, meaning PRETTY TOWN -was originally conceived with a separate sanitary sewer and a small primary treatment plant. Political troubles of 1991-1994 had forced a change of course, and all the houses were finally built with Septic Tanks.

But so far, no sanitary sewers had been built in the country because of unreliable water supply or a practical problem of maintenance cost, the socio-cultural habits of the population that would require an appropriate environmental education program, the investment costs related to the construction of such sanitary sewer and treatment systems. The country has a very low water consumption ratio.

Due to the unavailability or the inadequacy of piped water supply in Haiti, the household wastewater collection systems are the common practices: which is in accordance UNEP-CREP'S with Decision Tree for Appropriate Sewage Collection.

However, in the long run, small public or private sanitary sewer systems could be constructed.

Individual Wastewater Disposal Systems in Haiti

PIT Latrines

Construction of latrines with drywalls had been the most used in Haiti. Even in the richest private houses, it exists latrines in the backyard for the servants. The local technology is well established. The maintenance process is also well established. Good ventilation exists all year long. The lifespan of such a holding tank is more than five years for a family of ten people.

These latrines can have the following shapes:

- The simplest kind is one holding tank which is a temporary structure, and could be ventilated or not. It has a prefabricated cover with a piece of pipe for ventilation. Once it is full to a height of two-third (2/3), it is generally filled and covered up. The slab is then removed and transferred to a new location.

- The most advanced type is a double tank, well ventilated. It requires no real maintenance. It avoids contamination problems and is really affordable by the populations. The major disadvantage of this system lies in getting the proper sizing of the tank.

- A regular maintenance schedule is necessary with proper dumping of the resulting solid waste.

Aqua-Privy or Pit Latrine with Impervious Walls

In Haiti, this PIT latrine is used when the groundwater is relatively high: this is what is called in English aqua-privy.

Even though it functions as a latrine, it is not relying on ground infiltration of liquid wastewater.

The aqua-privy has a performance lower than the septic tank, but it could be integrated later in a sewer system.

Septic Tank

In Haiti, the septic tanks represent in the towns what the latrines constitute in the rural areas. The sinks, the toilets and the W.C. are connected into the septic tank.

The tank, with one or two compartments, separates the wastewaster from the sludge. The sludge compartment can be cleaned every two-year. The liquid is directed in an infiltration well, and could also be connected eventually to another system for infiltration in the surrounding ground.

In Haiti, many institutions had developed their own septic tank system. An effort is being made by a public enterprise dealing with social housing. The adopted system had been well tested so far. Developed into modules called "sanitary blocks", they had been used by housing projects in Haitian slums. The problems faced by the system are related to sanitary education, ignorance and maintenance cost for the community.

Construction of Community Sanitary Facilities

- Some Public toilets have been constructed in some areas like the public places, market places, hospitals and churches.
- Public sanitary facilities are necessary in HAITI, in the neighborhoods with very high population density like the slum areas of the biggest towns.
- In two slums of Port-au-Prince, namely Cité Soleil and Drouillard, public showers are added to the public toilet facilities.

Considerations About Industrial Wastewaters

In Haiti, where the industrial sector is not big, and mostly concentrated in Port-au-Prince, we are dealing mostly with manufactures, and factories concentrated in industrial parks. Those factories use regular septic tanks for their waste.

However, some industries, like soap factories, pharmaceutical industries use their own treatment processes for neutralizing their wastes, before dumping them in the street stormwaters.

Role of the Ministry of Environment (MOE)

- The Ministry of Environment is not yet involved in monitoring the treatment of the sanitary wastewaters, from private or industrial sources.
- The MOE is considering the introduction and the common use of the W.C. watersavers using only 1.5 gallons of water instead of the classic 5.0 gallons.
- The MOE is working on specific norms for wastewater pretreatment and treatment, for domestic and for industrial communities.
- The Environmental Impacts of community housing projects as well as industrial projects have to be studied, particularly for the groundwater pollution of their liquid wastes.

General Prospects

1. Settling or sedimentation tanks similar to the Imhoff tanks could be used sooner or later in Haiti.
2. Small separate sanitary sewers with facilities could be tried in some suburban areas with good water supplies and modern toilet facilities like water closets (W.C.).
3. In Port-au-Prince, portable toilets hare been introduced, whenever there is a big crowd for a special event, like the yearly Carnival, or a public concert or church event.
4. In some rural areas, aerated lagoons could be tried out.
5. Concerning the industrial wastes, they should be considered on a case-by-case basis.
6. Any new industrial park will take into account the sanitary facilities for the workers as well as the disposal of any industrial wastes.
7. The role of the Ministry of the Environment will be important as the official institution dealing with monitoring and establishing norms for groundwater pollution prevention.
8. The MOE should lobby for the future ratification of international convention dealing with industrial wastewater or with any persistent or non-biodegradable products.
9. In the fight against pollution by wastewater in Haiti, the MOE is studying an interconnection or symbiosis between some Conventions ratified by Haiti. And, as a National Focal Point, we

are considering an interface of such Conventions, in their relations with wastewater disposal and treatment.

- Pollution of water resources, by way of the groundwater pollution which is an objective of the CCD or Convention to Counter Desertification.

- Coastal pollution of the sea, of the coral reef, and the marine species (Convention upon Biodiversity)

- Pollution by dangerous wastes (covered under the Basel Convention)

- Considering the precarious situation of Wastewater disposal and Management in Haiti, the Ministry of Environment has been working for the official signing and ratifying of the Carthagen Convention. In the meantime, the MOE will participate in the future proceedings of the Wider Caribbean Region on that subject. The MOE is also showing a strong interest in the Protocol to Marine Pollution from Land Bused Sources and Activities (or LBSMP protocol). As a follow-up to the CEP Technical Report #40 we have improved on the table 2-3 of the report.

Conclusion

As a final word to this presentation, I would like to emphasize that the topic of wastewater disposal and treatment in Haiti, is part of an overall focus by the Ministry of Environment, on its way to preparing a National Environmental Action Plan, or NEAP for Haiti.

In fact, one of the themes already covered by a consultant concerns this matter.

Finally a specific Service of the MOE is the Service of Waste Management and Pollution Control which will be drafting criteria and impact statements norms to prevent and fight against groundwater pollution by domestic and industrial wastes.

Thank you very much for your patience and your understanding of my deep French accent.

God bless you.

References

USAID: "Manuel Pratique de l'Equipement Rural" (III) INSTALLATIONS SANITAIRES, Serie Techniques Américaines #104 Centre Régional d'Editions Techniques (CRET).

"Assainissement des villes de Province: Cap-Haïtien, Gonaïves, Saint-Marc Rapport B: Faisabilité", MSPPP, GKW Consult, Juillet 1990.

Appropriate Technology Sourcebook, Ken Dumond Danaman, 1993, Volunteers in Asia.

Parc Industriel SONAPI, Intermarketing Union Inc., Ig., N.Y., 1996.

MPCE, "Conférence Environnement et Développement dans la Caraïbe Francophone", 1990. Texte présenté par le MSPP.

"Appropriate Technology for Sewage Pollution Control in the Wider Caribbean Region, CEP Technical #40, 1998, UNEP.

Projet de Loi Organique, Ministère de l'Environnement (MDE), 1998.

"Preliminary Design Study of Sewerage and Stormwater Drainage, for Port-au-Prince and its environs" Engineering-Science, Inc., October 1972.

"Modules Sanitaires" Entreprise Publique de Promotion des Logements Sociaux, EPPLS, 1998.

Appropriate Technology for Portable Disposable Waste System, Firme JEDCO, Port-au-Prince, 1998.

Wastewater Management In Jamaica

Mrs Ianthe Smith
Senior Director, Pollution Control, Natural Resources Conservation Authority
53 $^{1}/_{2}$ Molynes Road, Kingston 10, JAMAICA
Tel: 876-923 5125, Fax: 876-923 5070

1.0 Introduction

This paper will look at the wastewater management systems in Jamaica, the regulatory framework, the current status of the treatment facilities and the areas in which improvements are necessary.

Wastewater for the purposes of this paper will refer to sewage and wastewater generated from industrial activities. The latter will be referred to as trade effluent.

2.0 Main operators of wastewater treatment facilities

There are a number of entities that operate wastewater treatment facilities in Jamaica. Sewage treatment facilities comprise the largest network of wastewater treatment facilities on the island. The following table shows a list of the major sewage treatment plant owners and operators. The National Water Commission (NWC) operates the largest number of plants and has a fairly large network of sewerage systems in major Cities and towns.

Table 2.1

Owner/operator	**Percentage owned**
National Water Commission	36
Ministry of Housing	14
Ministry of Education	4
Private developpers	5
Hotels & Resorts	16
Industries	8
Varied owners	17

Source of data: Environmental Control Division Annual Report 1997

Approximately 20% of the population island wide is connected to sewage treatment facilities. Major urban centres such as Kingston and St. Andrew, St. James and St. Catherine account for approximately 90% of the waste handled by the NWC.

The NWC will soon commission three new sewage treatment facilities in Ocho Rios, Montego Bay and Negril. These are tourist locales that have seen rapid growth in population resulting from migration into the areas. Consequently the infrastructure needs to be upgraded.

The Ministry of Environment and Housing usually operates sewage treatment plants associated with government housing projects but eventually hands these plants over to the NWC. Increasingly the NWC has indicated that they must agree to the proposed sewage treatment facility that they are eventually expected to take over. The NWC has also indicated that they are discouraging the use of package plants and promoting the use of sewage treatment ponds where applicable. There is a preference for low technology facilities so that the maintenance costs can be reduced.

The Ministry of Health operates the sewage treatment plants associated with their hospitals and health care facilities.

The Urban Development Corporation (UDC) operates a number of small sewage treatment plants across the island. The areas served by the Negril and Ocho Rios plants are to be covered by the new sewage treatment facilities being built by the NWC.

Hotels and resorts oftentimes have their own sewage treatment plants but it is expected that many will tie into the new NWC plants located in Negril, Ocho Rios and Montego Bay.

3.0 The Regulatory Framework

The Natural Resources Conservation Authority (NRCA) has the mandate for environmental management in Jamaica. The NRCA Act 1991, Section 12, indicates that a licence is needed for the discharge of wastewater into the environment and also for the alteration, reconstruction and construction of wastewater treatment facilities.

Effective January 1, 1997, the Permit and Licence regulations were promulgated and required that a Permit be obtained from the NRCA for the construction and operation of a new wastewater treatment facility and that a licence be obtained for the discharge of trade and sewage effluent.

The NRCA has been processing permit applications for new wastewater treatment facilities and licence applications for the discharge of effluent. The following table gives a breakdown of the number of permits granted for sewage and industrial wastewater treatment facilities and the number of licences granted for sewage and trade effluent discharge since the start of the permit and licence system in January 1997.

Table 3.1

Type of permit/licence granted	**Number**
Wastewater plant - permit	3
Sewage plant - permit	12
Trade effluent licence	9
Sewage effluent licence	14

The NRCA has established standards for sewage and trade effluent quality and meeting the standards is a condition of every licence granted. (See Appendix 1 for the trade and sewage effluent standards). It should be noted that there are two standards for sewage effluent, standards for existing facilities and those for new facilities. Currently permits and licences are only being granted for new facilities, existing being defined as those facilities that had all their statutory approvals in place prior to January 1, 1997.

The conditions of the licence usually require that there is self monitoring on a specified frequency to ensure that standards are being met. An Environmental Monitoring and Management Plan is usually requested of the entity that has been granted the Licence. The NRCA conducts post approval compliance monitoring to ensure that conditions are being met. Samples of effluent are also analysed by the NRCA laboratory.

Standard conditions included in sewage treatment facility permits and licences include the need for standby generators and standby pumps where there are mechanical plants. Also contingency plans in the case of malfunction of the plant must be lodged with the NRCA.

The regulations for the trade and sewage effluent standards are currently being prepared and it is expected that they will be finalised by March 1999. The NRCA will then be in a position to licence existing wastewater treatment facilities. There will also be regulations for waste discharge fees, which in principle will require the entity discharging effluent to pay a flat rate fee for that discharge once the effluent is in compliance with the NRCAs effluent standards. However if the effluent is out of compliance, an additional punitive fee will be imposed increasing geometrically for each day the effluent remains out of compliance. The aim is to encourage the polluter to fix the problem rather than to pay the penalty.

4.0 Current status of Wastewater Treatment Facilities

4.1 Section 17 Programme

The NRCA has already been working with some of the existing major generators of effluent through the Section 17 Programme. The Programme initially targeted those entities that discharged wastewater into the Kingston Harbour but has since expanded to include all sugar factories and distilleries, the bauxite/alumina plants, the coffee pulperies as well as other establishments known to generate sewage and trade effluent.

Under the Programme the NRCA gets information by way of a questionnaire every four months on the pollution control and waste management practices of the entity. Effluent quality is one of the areas reported on. Verification monitoring is done by the NRCA to ensure that the data provided is indeed accurate. It is expected that these entities will eventually be incorporated into the licencing system for existing entities that is expected to start in the 1999/2000 fiscal year.

Since the inception of the Section 17 programme in 1993, the NRCA has issued 213 notices to industries and has conducted verification monitoring visits to approximately 70 % of the industries. Based on the reports submitted and the visits done, it is clear that there is still a lot of work to be done. More than 90% of the entities with an effluent discharge do not consistently meet the standards. There has been some improvement in the quality of the effluent and about 30% are making serious efforts to achieve compliance.

4.2 Trade and Sewage Effluent Quality

The sewage effluent quality from the NWC sewage treatment facilities are inconsistent and more than 85% of the 48 plants do not meet the sewage effluent standards. The NWC is still to present the NRCA with a strategic plan on how they intend to bring their existing plants into compliance with the standards.

The NWC is about to commission three new sewage treatment plants in Negril, Ocho Rios and Montego Bay. These plants have been plagued with a number of problems during the construction phase that has resulted in lengthy delays. It is expected that the plants will be commissioned by December 1998.

However there still exists the problem of interconnection to the sewerage system by those entities that generate wastewater. This presents a challenge to the NWC as there is no legislation binding the wastewater generator to interconnect to the sewerage system. The sewage treatment plants will not realise their true purpose if there are insufficient connections to the sewerage system.

Industrial wastewater treatment facilities in the agro-industrial sector have been plagued with poor trade effluent discharge quality. This is of particular concern in the sugar industry, coffee industry, distilleries, and abattoirs. Wastewater tends to have high Biochemical Oxygen Demand (BOD), Total suspended and dissolved solids. End of pipe treatment options tend to be looked at as the first solution to the problems, however the NRCA has been encouraging waste generators to look at waste minimization and cleaner production as alternative solutions which usually end up saving scarce financial resources as water and energy consumption are reduced.

The bauxite industry has been known to have problems with trade effluent that has a high sodium content. The power generation sector has problems with the temperature of their effluent discharge and the management of oily wastes.

It is expected that many industries will wait until the legislation to licence the effluent discharge from existing entities is in place before they get their house in order. Those that have responded to the NRCA’s advice to get started with their plan to achieve compliance will be ahead of the game.

Where there are genuine cases of difficulty in achieving compliance, the NRCA will deal with these on a case by case basis. We realise that changes cannot take place overnight but we expect a plan of action to be submitted to the NRCA so that we can monitor the progress being made.

4.3 The CWIP Project

There is the Coastal Water Quality Improvement Project (CWIP) a USAID funded project undertaken in collaboration with the NRCA, that has been working with the NWC to help them define their plans on how they will address Operation and Maintenance issues pertaining to their sewage treatment plants.

The CWIP project has been assisting the NWC to explore the options of Public/Private partnerships for operating the plants and has conducted a Training Needs Assessment for the operators of the plants. It is expected that the assistance provided by this project will help the NWC tackle some of the long-standing problems associated with the operation and maintenance of their plants.

5.0 The Future

The NRCA will continue to work with waste generators to address the problem of poor quality effluent discharge so that the rivers, marine environment and the land will not be degraded. This can only be achieved through a partnership arrangement between the waste generators and the NRCA.

The licencing system for new and existing entities and the waste discharge fees will provide the regulatory regime for wastewater management. The NRCA realises that incentives need to be provided as well and is actively looking at ways in which we can also provide the carrot and not just use the stick.

Mexico

Dr Felipe Arreguin Cortes
Tratamiento y Calidad de Agua, Instituto Mexicano de Techologia del Agua (IMTA)
Paseo Cuauhuahuac 8532, Jiutepec, Morelos, C.P. 62550, MEXICO
Tel: 52-73-194381, Tel: 52-73-194000 ext. 543, Fax: 52-73-194381, Email: arreguin@tlaloc.imta.mx

1.0 Water in Mexico

The almost two million square kilometer surface area comprised by Mexico has an average annual rainfall of 777 millimeters, equivalent to 1522 cubic kilometers. However, the spatial distribution is quite irregular. Approximately 42% of the country, mainly to the north, receives an average annual rainfall of less than 500 millimeters and in some cases, near the Colorado River, less than 50 millimeters. On the other extreme, 7% of the nation has an average annual rainfall above 2000 millimeters, with localized regions where more than 5000 millimeters of rain reach the ground. In general, 80% of the rain occurs during the summer months.

Of the water that falls on Mexico, 27% is transformed into surface runoff that is 410 cubic kilometers is concentrated in 314 basins. The distribution here is irregular as well. One half of the runoff is localized to the southeast, area that geographically is 20% of the nation, while only 4% is found in the northern region, which is about 30% of the territorial extension.

The storage capacity of Mexican lakes and lagoons, some 14 cubic kilometers, and dams, another 189 cubic kilometers, account for 47% of the average annual runoff.

Of the rain that infiltrates, 48 cubic kilometers renews the aquifers. In the irrigated areas, aquifers receive an artificial recharge of an additional 15 cubic kilometers. Finally, there are estimates that 110 cubic kilometers of the water in aquifers can be used only once.

The availability of water per person is also extremely variable across the nation. There are regions with 200 cubic meters available for each person, and others with 33 000. On the average, each inhabitant can use 5 200 cubic meters each year.

2.0 Water Use

In 1997, the population in Mexico reached 94.3 million of which 13.4 million did not have drinking water in their homes and 26 million did not have access to sewerage service. This deficiency was more marked in rural areas. It has been estimated that 8.5 cubic kilometers of water are extracted to cover the domestic demand. Some 95% of the water supplied to the communities is disinfected and 2.2 cubic kilometers is potabilized each year.

Mexicans crop 20 million hectares of which 6.2 receive irrigation water. The remainder use dry farming alone or with technological improvements. In 1994, 61.2 cubic kilometers of water was extracted for this purpose: 41.1 from surface sites and 20.1 from groundwater sources.

Industries located in suburban and rural areas used 2.5 cubic kilometres of water, while thermo- and hydroelectric plants required 113.5 in 1997.

3.0 Water Pollution In Mexico

Based on quality assessment studies carried out in 218 basins that cover 77% of the nation and that account for some 93% of the population, 72% of the industrial production and 98% of the irrigated land, 20 of the basins were responsible for 89% of the total pollutant load, as measured by the biochemical oxygen demand (BOD). Four basins receive 50% of all wastewater discharged.

The most polluted aquifers are underlying great cities and the agricultural areas. These last are affected by the leaching of the agrochemicals in use.

Deforestation has also contributed to the degradation of the water quality in the nation's basins.

Of the 315 municipal drinking water treatment plants, the 260 on line treated 74,423 lps. From the inflow of water and community activities, 184,000 lps of wastewater were generated. The installed capacity for the treatment of these municipal wastewater discharges is 61,653 lps in 821 plants; in fact, only 639 (77%) of the plants were operating and treated 39,389 lps. The nation's industries generate 82,000 lps of wastewater with varied compositions and characteristics. Most of the wastes are highly polluting if left untreated. The largest sources of wastewater are in the areas of sugar refining, chemistry, cellulose and paper, petroleum, soft drinks, textiles, iron works and food preparation.

4.0 National Water Commission

The National Water Commission (CNA), is the water authority in Mexico, was created in 1989. As a promoter of change, the CNA must become fully involved in the evolution of an administration capable of fulfilling the demands made on it through the decentralization of routine processes, the delegation of authority and responsibility to local officials, the creation of a realistic rate scale for water services and the development of regulations and a new water culture.

To face these challenges in Mexico, the CNA developed its Hydraulic Program 1995-2000, with a view to reducing the underdevelopment and limitations in water availability, advancing the integral reclamation of basins, assuring equality of usage under the law, contributing to the sustainable development of the nation and expanding society's participation in the planning and use of water. Outstanding within the Mexican Hydraulic Program is the Water Management Modernization Plan designed to provide cutting-edge technology to the water sector.

5.0 The Mexican Institute Of Water Technology (IMTA)

The Institute was created in 1986, and its mission is:

"Carrying out research, development, adaptation and transfer of technology, rendering of technological services and preparing qualified human resources, to administer, conserve and rehabilitate water to contribute to the sustainable development of the country."

5.1 Water Treatment and Quality

The IMTA has six Divisions, one of them is the Water Treatment and Quality Division. This Division comprises four areas that specialize in the conservation of water quality, environmental impact assessments, drinking water treatment and wastewater treatment and recycling with research in analytical chemistry, microbiology, environmental impact, hydrobiology, industrial wastewater treatment, municipal wastewater treatment, drinking water treatment and quality control.

5.2V Mission

Carry out research to adapt, develop and transfer technology for the improvement and conservation of water quality and the related natural resources, to achieve sustainable environmental development.

This Division has four areas, that will be described:

Drinking water treatment area

It studies of the characteristics of drinking water sources in Mexico, and the feasibility, operating conditions and efficiency of technology applied to drinking water treatment plants. The projects are proposed in accordance with the needs of the nation. Most research is centered on the application of feasible and economical methods to treat water from natural sources.

Water Quality Area

It makes diagnosis, evaluation and propose solutions of water-related problems in the field of analytical chemistry, environmental microbiology and hydrogeochemistry.

Hydrobiology and environmental assessment area

It studies the aquatic ecology of fish, invertebrates, plants and weeds in streams and lakes. These streams are also used to evaluate the impact of industrial discharges and pesticides, and the effects of impoundments and modifications in the natural flow regimens on invertebrates and fish. The biological response is also used to assess the impact of environmental stresses on river biota. The studies are carried out by multidisciplinary teams of hydrologists, chemists, botanists and zoologists.

Wastewater treatment area

This area develop computer programs for the design of wastewater treatment plants and sewerage networks. Mathematical modeling of treatment systems and simulations of unitary processes. Laboratory-scale conventional and advanced treatment tests and large-scale sedimentation, jar, chemical oxidation, adsorption, microorganism adaptation, biochemical behavior and specific sludge resistance tests. Evaluation of unitary process efficiency in the removal of pollutants from wastewater and other specific methods. Definition of adequate treatment sequences and design parameters, depending on the required effluent quality for reuse or discharge to a receiving body.

6.0 Cutting Edge Technology or Adequate Technology

Basic treatment methods and technology can be divided in two large groups: simple or appropriate, and innovative or sophisticated. The title simple does not imply a low efficiency but that may require plants with reduced energy consumption and uncomplicated technology for construction and operation, and that may use systems based on natural transformations, such as stabilization ponds and soil infiltration systems or, finally, the use of aquatic plants and systems, commonly known as wetlands.

The concept of innovation is the opposite of this, in the sense that the treatment systems are complicated in the construction materials required, the equipment used and the controls needed, and much more costly. There are several classes of innovative technological concepts, based on mechanical and biological schemes, mechanical and chemical schemes, and mechanical, biological and chemical schemes. These systems usually require highly trained operators and large investments in operation and construction.

The concept of the Best Available Technology Economically Available (BATEA) should be adopted in our countries. It is a made-to-order measure that satisfies the specific needs for each case, each site and each type of wastewater.

Conceptually, BATEA means:

- Prevent the discharge of priority pollutants to the environment or when this was not possible, reduce their discharge to a minimum and transform them to innocuous compounds.

- Transform pollutants that may be harmful when discharged in the environment, such as oxygen consuming products that, as such, are non-toxic.

- Reduce environmental pollution as a whole, by adopting the Best Available Technology Economically Available for the substances to be discharged.

In practical terms, BATEA for the treatment of wastewater implies

- Elimination of priority pollutants when possible through the selection of raw materials, modifications in the processes or use and adoption of clean technology.

- Prevention of the dilution of polluting discharges.

- Measurement and constant monitoring of effluents and pollutants.

- Separation of discharges containing priority pollutants for individual treatment.

- Recovery of materials for reuse, when possible.

7.0 Final Considerations

Sustainable development is understood as the administration and conservation of natural resources and the focussing of technological and institutional change to assure the continued satisfaction of human needs for current and future generations. This sustainable development conserves land, water, plant and animal genetic reserves, does not degrade the environment and is technically appropriate, economically feasible and socially acceptable (FAO).

In this context, human beings and the capacity of the ecosystems to maintain life are at the center. In the area of ecologically sustainable development, the existence of extreme poverty and the degradation and pollution of the ecosystems are basic concerns that should be surmounted. For most industries, the production, control and disposal of wastewater has become an integral part of the production strategy and costs. As the cost of treating and disposing of wastes increases, more sophisticated treatment becomes feasible. However, the basic, simple methods should not be forgotten - policies to minimize the generation of wastewater, reduce water consumption and decrease the requirements of treatment processes. Minimization should be a prime consideration in any pollution control strategy and treatment philosophy.

All human beings, institutions, organizations and countries that seek to live in harmony with their environment should have, as environmental and ecological goals:

- Reduce and, ideally, eliminate, pollution at its source,
- prevent the accumulation of non-degradable toxic substances,
- reuse water and other materials,
- prevent the transport of pollutants,
- avoid the exhaustion of natural resources,
- administer energy consumption,
- develop and use non-polluting energy sources,
- minimize desertification, and
- prevent water-bourne diseases.

The ecological perspective starts with a global vision and an understanding of how the different components of nature (including the human being) interact through patterns that tend toward equilibrium and that persist through time. The need to move toward sustainable development requires a change in the general paradigm towards an ecological focus, a dynamic environmental education based on these concepts, and sustained support of the research activities, basic and applied, that will give forth the technological development activities needed by humanity.

Wastewater Collection and Treatment Technologies in the Netherlands Antilles

Rodriguez, Arthur A. B.Sc., Ing. Oleana, Patricio D., Department of Public Works
Curaçao, Netherlands Antilles

Department of Public Works (DOW), Subdivision Sanitary Engineering, Head Process Engineering
Landhuis Parera, PO 3227, CURACAO, N. A.

Tel/Fax: (599-9) 868-6866, Tel: (599-9) 433-4444 (Head Office)
Fax: (599-9) 461-7969 (Head Office), E-mail: curzuiv@cura.net

The Netherlands Antilles is part of the Kingdom of the Netherlands and consists of five islands:

	Island	**Population (inhabitants)**
Windward Islands	Saba	1.300
	Saint Eustatius	2.300
	Saint Maarten	35.000
Leeward Islands	Bonaire	15.000
	Curacao	150.000

Saba and Saint Eustatius

Because of their scale, wastewater management has not been an issue as yet.

Saint Maarten

The infrastructure did not keep track with the rapid increase of the population and tourism. In Sint Maarten a small "Trickling filter" filled with synthetic material, primary sedimentation and a settling tank is in use. An expansion of the sewerage and an upgrade/expansion of the treatment plant are now been planned.

Bonaire

Bonaire's main income derives from the diving tourism. The nutrient pollution originating from direct or indirect sewage discharges is the main threat for this natural resource. Bonaire has an attractive marine environment, especially for divers. They support some of the best remaining coral reefs in the Caribbean. The reefs are internationally acclaimed for their outstanding natural beauty and their high diversity as well as the richness of fishes and other species that live near the reefs. Bonaire is now in the stage of developing a plan to collect, transport and treat sewage. In the first phase of the project the coastal areas have the highest priority. The effluent will be re-used for agricultural, horticultural and landscaping purposes. The European Union and the Netherlands will finance the project.

Curacao

In Curacao the Department of Public Works (DOW) is in charge of wastewater management. The environmental management system is in accordance with international standards. DOW is in charge of the planning by developing mid and long-term plans, as well as recommendations on investment plans and financial requirements. A Wastewater Master Plan has been developed.

The objective of the Wastewater Policy is:
In order to prevent nuisance, health and environmental hazards, sewage collection and treatment is recommended, taking into account the social, economic and financial limitations. The effluents of the treatment plants should be qualitatively adequate for reuse in agriculture, horticulture and landscaping.

The technical, legal, institutional and financial aspects of wastewater management have been outline in this document. The planning period is 1990 – 2005.

Sewerage:

The sewerage is a combination of gravity (263 km – 82%) and pressurized (54 km – 18%) sewers and pump stations.

In the inner city, public-housing areas, highly populated areas, and areas with a high groundwater level, sewerage has been constructed.

Department of Public Works is now working on standardization of sewers, and (under ground) pump stations in order to keep the maintenance simple and the stock of spare parts limited.

Components:

- Control vale (for automatic control of a bi-directional sewer managing)
- Buffer stock (to avoid dumping by a calamity)
- Bar screen of 10 cm
- One mixer (to homogenize the wastewater, which prevents sedimentation and floating material)
- Tow wet submersible pumps
- Dry arrangement of the moving parts (check valve, valve, pressure gauge, pH and EC)
- Compost filter (to prevent unpleasant odor)

- Soft start / stop (in order to prevent broken pipelines by increase of the sudden pressure)
- Telemetric system (so the pump station can also be managed by remote control and to get management information at any time
- Telephone communication

Four Sewage Treatment Plants (STP):

In Curacao we have four treatment plants.

STP – Tera Cora (1984):

This is a small STP in an urban area; with a load capacity of 4000 population equivalents (p.e.) and a daily flow of 300 m^3/d; trickling filter filled with synthetic material, combined with an Imhoff tank and maturation ponds.

The Slaughterhouse STP (1988):

The load capacity is 2700 p.e. and a flow of 65 m^3/d; trickling filter with forced air down stream, combined with an Imhoff tank, and a settling tank; discharges into a bay.

The main Sewer Treatment Plants of Curacao are Klein Hofje and Klein Kwartier. The influent of Klein Hofje and Klein Kwartier consists of domestic and some industrial sewage and storm water of the inner city. Household sewage that has been collected by trucks (septic tanks or cesspits) can be discharged at the STP, unless the pH and conductivity (EC) are between limits. In general, industrial sewage will not be accepted, because of possible presence of toxic components. Exceptions are possible.

The control of the water and sludge quality is being executed in a laboratory.

The effluent should be of a certain quality in order to prevent health hazards or damage of crops and landscaping. The re-use of the effluent is restricted.

STP – Klein Hofje (1986):

Type: Trickling filter with 950m^3 synthetic material and 3000m^3/h forced air down stream.

Design Parameters:

Pollutions Load	**(p.e.)**	**40.000**	
Daily Flow Rate	(m^3/d)	2.300	(3500)
Hydraulic Peak Flow	(m^3/h)	230	
Maximum Peak Flow	(m^3/h)	350	
BOD	(g/p.e./d)	50	(7)
TKN	(g N/p.e./d)	10	
Suspended Solids	(g/p.e./d)	60	
BOD Load	(kg/d)	200	
TKN Load	(kg/d)	400	
Suspended Solids	(kg/d)	2400	

The trickling filter has been designed for a hydraulic flow of 2300 m^3/d and a pollution load of 50g BPD/p.e./d. The ratio between load and flow is not as designed. The STP receives a pollution load of only 7g BOD/p.e./d. Part of the pollution stays in the sewers or pumping houses. The hygienic efficiency of the maturation ponds is the limited factor, while the hydraulic flow can be increased till 3500 m^3/d without further expansion.

Components:

Water Line: Gully Emptier discharge pit
Bar rack (mechanically cleaned rake) 15 mm
Screening press
Influent pump station (2 x 200 m^3/h)
Primary sedimentation, Dortmundtank (4 x 12.5 m^3/h)
Trickling filter (synthetic material)
Forced air (ventilator with extractor fan, 3000 m^3/h)
Settling tank, Miedertank (2 x 20 m^3/h)
Effluent quantity measurement, ultra sonic
Maturation ponds (7 x pc. – 19.000m^2 & 28.500m^3)
Effluent pump station in combination with buffer capacity (2 x 250 m^3/h)
Fully automatic effluent back flushing filters, slot type candles, pore 75 pm
Effluent storage tank (4071m^3)
Effluent distribution system (pump station – 3 to 4 bar)

Sludge Line: Grit chamber/washer (10 – 20 m3/m2 h)
Gravity sludge thickener (20 m3 /h)
Anaerobic sludge digestion (1040m3 – 32 C – circulation by pumping 20m3/h)
Electrical heating element (10 x 1.8 kW) in thermal oil
Gas compressor (220 m3 /h for mixing the contents of the digester)
Gas holder (100 m3)
Final sludge thickener (20 m3 /h)
Drying beds with drain system (1600 m2)
Sludge storage (280 m2)
Gas engine and generator (electricity 80 kW – 900 m3 CH4/d)

Treatment Results:

		Effluent	**Efficiency**	
BOD	(mg/l)	31	80%	after polishing
COD	(mg/l)	117	68	
COD/BOD		2.19		
NH_4	(mg/l)	19		
TKN	(mg/l)	28	56	
P_{tot}	(mg/l)	32	11	
NO_2	(mg/l)	2.6		
NO_3	(mg/l)	4.3		
Suspended Solids	(kg/d)	n.d.		
Fecal Coliforms	(cfu/100ml)	1012		

STP – Klein Kwartier (1983):

Type: Oxidation ditch activated sludge (a small oxidation ditch, 4000 p.e. / 160 m^3/d, is being expanded with 31.000 p.e.; this is that first phase expansion).

Design Parameters:

Pollutions Load	**(p.e.)**	**31.000**
Daily Flow	(m^3/d)	2.500
Hydraulic Flow	(m^3/h)	250
BOD	(g/p.e./d)	35
Sludge Load	(kg BOD/ kg SS/d)	0.07
Sludge Concentration	(kg SS/m^3)	4
OC/Load	(kg 02/kg BOD)	3.0
Sludge Volume Index	(ml/g)	100
Oxygen Demand	(kg 02/h)	136

Components:

Water Line: Gully Emptier Discharge Pit (which is automatically controlled)
Step Screen (automatic on level control 340 m3/h) 5 mm
Screening press (automatically controlled)
Grit chamber (349 m3/h)
Grit washer (15 m3/h)
Grease separator (17 m3 – t+5 min.)
Oxidation ditch Activated-Sludge (3875 m3 – 390 m3/h)
Mechanical aerator (horizontal axis type) 4 x (5.5 * 0.87m) 34 kg 02/h
Settling tank (418 m3 – 209 m3/h)
Return sludge 105 m3/h
Effluent quantity measurement (ultra sonic – max. 334 m3/h)
Ground infiltration (3 x infiltration pounds – 265 m3/h)
Effluent distribution (deep well pumps 5 x 10 m3/h – effluent 50 m3/h)

Sludge line: Sludge thickener (20 m3/h)
Drying fields / drainage system (1600 m2)

Management:

The following aspects are part of the management:

Development plans – institutional development – quality assurance systems – research and inspection.

All our personnel should have electrical, mechanical and process control backgrounds (EMP-man). To achieve this they will be trained in the Netherlands.

- The sewerage Treatment Plant Klein Kwartier will be fully automated and can be managed by remote control. In case of calamities automatically alternative sewage routes or discharges are being activated.
- The daily management will be based on: Suspended Solids (ss = 4 gl) – Sludge Volume – Sludge Volume Index (SV1 = 100 ml/g) – BOD load (kg BOD/m^3d) – Hydraulic load (m^3/m^3d) – Aerated time (V/Q_d = 2.5/3 d) – Oxygen concentration (mg/l) – Sludge age (20/30 d) – Denitrification – Effluent quality (10 mg BOD/l – Fecal coli)

The Problems and the Solutions

You are welcome to share any alternative or additional solution you may have.

1. Gravity and Pressurized Sewers:

    - Because the landscape is very hilly, frequently broken pressurized pipelines occur due to hammer stroke.

To resolve this problem we have decided to introduce a soft starter with option soft stop at the pump stations.

- *As a result of overdue maintenance of the gravity sewers, the pipelines became overloaded by sedimentation.*

We have acquired a gully emptier/sewer cleaner to do the preventive maintenance. For the pressurized sewer we keep the velocity as designed 1.6 m/sec.

- *Public awareness is very important for depositing their garbage in the sewers or pits.*

The government is working on a structural plan of awareness.

2. Pump Stations (36) with Wet Submersible Pump:

    - Different wet compartments of the pump stations are heavily corroded by the high concentration of H_2S produced by putrefaction.

First action is to prevent the sedimentation, which means elimination of the anaerobic process.

The pipelines are covered with fiberglass, and all moving parts are arranged in a dry compartment.

To prevent sedimentation we have installed a mixer (submersible pump without pump-house) to homogenize the sewage before transport.

- To prevent unpleasant odor in highly populated areas all pump stations are provided with:

A compost filter which works with forced air.

3. Sewage Treatment Plants:

   The treatment efficiency of the STP-Klein Hofje is insufficient due to:

   - The total Suspended Solids (TSS) of the influent which is very low;
   - Algae growth in the maturation ponds which means BOD increase;
   - Limited absorption of UV-radiation (algae), which has a negative effect on the hygienic quality.
   - To get a higher pollution load at Klein Hofje, all pump stations will be provided with a mixer.
   - Enzyme will be dosed in the trickling filter to get a better purification efficiency.
   - Propeller aerator to reduce or eliminate the algae growth in the maturation ponds will be installed.
   - The bacterial quality is insufficient, because the retention time in the maturation ponds is too short. The use of an activated carbon filter and UV-disinfecting as tertiary treatment is being studied at this moment.
   - To eliminate (stripping) the H_2S production in the anaerobic digester, $FeCl_3$ is dosed into the sludge digester.
   - We use a computerized maintenance system, which gives monthly information.

All parts must be imported, so stock management is very important.

Waste Water Management – St Kitts

Errol A Rawlins
Deputy Chief Environmental Health Officer

St Kitts is a relatively small island approximately 164 square kilometres with a population of estimated as of June 1997 – 33,500.

The island is approximately 37 km long and 5 km wide at its widest point and is dominated by a mountain range with tropical forests. Cultivated fertile valleys closer to the coast support agricultural production.

The water supply of St Kitts consists of surface and sub-surface or ground water.

Despite the comparatively small area and population, the island has a comparatively large and diverse quantity of industrial activities such as sugar, distillery, brewery, textile, electronics, fabrication and food processing to name a few.

Like other Caribbean countries the increased supply of potable water, the growing standard of living and increased industrialization including tourism has resulted in an increase of waste water to be disposed of.

The most widely used system of sewage disposal is the septic tank and soakaway. The island has no central sewage collection, treatment and disposal facilities.

There are at least six (6) package treatment plants on the island. There are three (3) Extended Aeration Plants, one (1) Rotating Biological Contactor, one (1) Leach Field System and one (1) Activated Sludge Process.

Two of the extended aeration plants are situated at hotels while one is situated at the main hospital. The Rotating Biological Contactor is situated at a housing project in the capital city.

Approximately eighty-two (82) percent of occupied premises utilizes the septic tank and soakaway system. The pit privy is also being utilized by a cross section of the general population.

Sources of wastewater include domestic, industrial, and commercial.

Domestic wastewater is either disposed of into septic tanks, soakaways or channeled to public drains which ends into the marine coastline.

Liquid waste produce from some industries either enter into soakaways or drains which enter the coastline.

Wastewater entering the marine coastline is likely to impact on the marine ecosystems.

The operational status of most of the package treatment plants are questionable due to the lack of proper maintenance and trained personnel. Effluent from some of these plants enters the marine environment.

The coastal waters of the Basseterre Harbour, Lime Kiln Bay and Frigate Bay are monitored on a monthly basis for faecal coliform and other physical parameters. There are eight (8) sampling points in the Basseterre Harbour, two (2) sampling points in Lime Kiln Bay and five (5) sampling points in Frigate Bay.

The installation of a central sewage collection system for Basseterre is the only practical solution to the liquid waste problems being experienced.

The connection between poor liquid waste disposal practices and adverse effects on health is well known, but there is lack of data specific to St Kitts linking current public health impacts.

The Environmental Health Department continues to collect data on the coastal pollution monitoring programme.

The Public Health Act #20 of 1969 gives the Minister of Health the authority to make regulations with respect to waste water and its disposal.

The National Conservation and Environment Protection Act #5 of 1987, gives some measure of protection to the marine environment.

Wastewater Treatment in St. Vincent & The Grenadines

Brian George
Central Water and Sewerage Authority

Introduction

St. Vincent and the Grenadines (SVG) presently has a population of approximately 120,000 persons with the capital, Kingstown, having a resident population of about 15,000 to 16,000 people. Environmental issues affecting health and preventing further degradation of the environment are becoming focal points of attention, as illustrated by the implementation of the OECS Solid Waste project, and the studies for the sewerage treatment project.

Predominantly throughout St. Vincent and the Grenadines, sewage treatment consists of septic tanks for collection and treatment and soakaway systems for disposal of effluent. This applies to both domestic households and commercial premises such as hotels, etc. As such, sewered areas are basically areas of central Kingstown and a small area in Arnos Vale, not too far from the capital.

The two major areas of focus in SVG as related to sewage treatment is the area of central Kingstown and its surrounding environs, and the South Coast area of the island which is an extremely densely populated area with several hotels and beaches all in the same locality. The latter is of great concern due to the political and economic thrust to greater developed tourism. The Kingstown area has quantities of waste generated from the several restaurants and other food establishments as would be expected with any other capital city, however, the majority is domestic sewage. Hence, industrial waste is not a concern eliminating the threat of heavy metals.

With these factors in mind the Central Water and Sewerage Authority of SVG under took to create a project to address wastewater treatment. As a result, extensive feasibility studies were done to ascertain and focus on key issues of such a project. The justification for the project was derived from the fact that reduced pollution and improved health conditions can be achieved from the implementation of a sewage treatment project. As well as protecting health internally the outward affects of pollution on tourism are eliminated thus helping the economic development of the country.

The focus of this paper is the sewerage and treatment systems for the Kingstown and South Coast areas, the technologies presently implemented and proposed for future development, and the environmental implications and rational behind certain decisions.

Present Methods of Wastewater Treatment and Disposal

Kingstown

As discussed previously, only the central Kingstown area is sewered. The system consists of 5.8 km of PVC sewers ranging in size from 150 mm (6") to 600 mm (24"). The system was constructed in the early 1970's with provision for future extension to serve an expanded area and other parts at a later date. All sewers feed to a collection tank on the sea front, having a capacity of 54,000 gals. The collection facility is in fair to poor condition and requires extensive refurbishment.

Collected sewage is disposed via marine disposal, with sewage being pumped out to sea through a 400 mm PVC outfall. This outfall is approximately 1500m (4800 ft) long and is supposed to discharge sewage outside of the Kingstown bay locality and into the sea currents where it does not pose a threat to marine coastal life and man. However, the outfall is in very poor condition and has several cracks and breaks along its length. Hence, sewage is pumped into the sea much closer to the coastline than originally intended, only 300m (100 ft) off the nearest bay.

Collection and disposal aside, collected sewage is not treated in any manner. Even the comminutor which was at the inlet of the collection tank has not functioned for a long time now and the by-pass arrangement has had to be utilized permanently. This consists of a large grill that is difficult to clean and regularly blocks.

Recent studies have shown that due to the depth of the outfall at the location of the break and the quantity and duration of the sewage pumping regime, environmental impacts to date have been minimal. This is due mainly to the high dilution factor which is achieved on discharge of the sewage, and the distance of the break from the shoreline is luckily adequate. Usual signs of negative environmental impacts are minimal, e.g. there are very few signs of non biodegradable deposits on Edinboro beach (nearest coastline) and bathing water standards are marginally acceptable as compared to European and EPA standards. Marine life also still appears to be thriving in this area.

South Coast

The south coast is separated from the capital Kingstown by the highlands of Cane Garden, having an elevation of approximately 330 ft. Along this coastline, there are a number of beaches bounded by hotels, and the area is also densely populated. Many of these hotels make an attempt to have some form of septic tank and soakaway system but this is problematic due to the proximity to the coastline and resultant high water table level. Instances arise whereby sewage from seepage discharges straight to sea and, in all cases, sullage (grey water) from kitchens and bathrooms is discharged straight to sea through stormwater drains. The result is an extremely heavily stressed environment in this area. Practically all corals have died and bathing water standards are of critical concern. It should also be remembered that the absence of corals negates from nature the ability to regenerate its beaches with sand, which is a concern when one considers tourism.

Options of Technologies/Design Proposals

It is vividly obvious that the present state of affairs must be corrected. In Kingstown it is imperative that collected sewage undergoes some form of treatment prior to discharge as marine disposal is still considered to be the most feasible practical option, as re-use needs are limited and conveyance to the point of reuse is an issue.

The present Kingstown site combined with the reclaimed lands immediately next to it is still a relatively small parcel of land. Hence, land space is an issue, odour nuisances from treatment is also a key issue as the site is centrally located in an extremely commercialised area. It is also evident that the South Coast area must be sewered, resulting in a need to treat the sewage which is collected in this area.

The recent study findings recommend that presently and for several years to come, preliminary treatment only shall be required for sewage treatment. The rationale behind such a recommendation derives its basis from the fact that many treatment processes were developed to produce safe effluent discharges to rivers and enclosed water courses. It is also considered safe practice to give little if any treatment to discharge made to the open sea. Once discharges are not excessively large, the sea is considered to have sufficient self-purifying capacity especially when combined with suitably favorable sea currents. The latter has been proven by extensive recent investigations such as drogue tracking and dye tests. However, due to public awareness and political reasons, this thinking has changed in recent years and there has been increasing legislation to mitigate against sewage discharge to sea without minimal treatment whether justified or otherwise on a scientific or biological basis.

It has then been decided to adopt only preliminary treatment for the next 10 years or so, and then at some later date necessitated by possible implemented legislation and environmental conditions further treatment shall be constructed. However, with limited land space available, it is difficult to incorporate and hold secondary treatment at the Kingstown site. As an alternative, there is a parcel of land on the South Coast at Arnos Vale which is presently a dump site, but is soon due to be closed. It is therefore proposed to construct a treatment plant at that location. Not only is more (?) land available but odour would not be such a nuisance.

Bearing these factors in mind, it is proposed to make provision for preliminary treatment for both Kingstown and South Coast flows in Kingstown for a period of the next 10 years. In this scenario, a force main would be installed to take the flows from the South Coast over and through the highland area of Cane Garden and into Kingstown. The proposal is to refurbish the Kingstown sewage collection facility by installing self- cleaning screens with provisions for washing screenings making them suitable for transportation. The facility shall be enclosed for odour control utilizing a biological filter formed from local coconut fiber.

In the future when it may become necessary to have further treatment, it is proposed to construct a treatment plant on the lands at Arnos Vale. In this scenario all sewage shall be pumped to Arnos Vale. The recommended treatment process shall then be the Extended Aeration Process which is low in capital cost, robust, easy to maintain and operate, odour free and produces a sludge which is well oxidized and stable compared with sludge produced by other processes. It is important to note that due to lack of available land space in Kingstown, Lamella Plate Separators would be required, which are high in capital and operational cost, and have a high maintenance requirement, which would be a problem in St. Vincent.

The proposal is also to simply produce cake sludge by mechanical dewatering and dispose to landfills and use on land to improve soil fertility. In this proposal, a new outfall for marine disposal will have to be constructed at Arnos Vale.

Future Direction

It is proposed to have a phased approach for implementation of the project. Under stage 1, several items shall be completed.

i. New connections of premises not yet connected to the existing system.
ii. Inclusion and necessary changes to have sullage discharged into sewers
iii. Extension of Kingstown sewage catchment to include nearby surrounding areas of Kingstown
iv. Refurbishment of sewage collection facility i.e. construction of screens, enclosing of facility
v. Construction of a new out-fall in Kingstown.
vi. Construct sewers in South Coast area.
vii. Construct pumping stations and mains to transmit sewage to Kingstown.

This phase is estimated to cost approximately EC$23,000,000.

Stage 2 shall basically consist of construction of the treatment plant at Arnos Vale, and construction of a new outfall at Arnos Vale. This, however, shall not take place for another 10 years at least. This phase should cost an additional EC$17,000,000.

Conclusions

In developing the project further more investigation and thought needs to be put into the type of treatment adopted, and ensure that the process adopted works under our local conditions. Work is still yet to be done on costing and design of the outfall at Arnos Vale. Also, it must be considered how phasing impacts on the design and construction, e.g. can pumping simply be reversed when the treatment plant is at Arnos Vale. However, there is now a firm grasp of what is required to address the wastewater treatment needs in SVG.

List of References

Howard Humphreys & Partners Ltd.
Study to review the treatment and disposal of Kingstown's Sewerage, St. Vincent, 1997.

Metcalf & Eddy
Wastewater Engineering – Treatment, Disposal & Reuse, 3rd Edition, McGraw Hill.

Persons Consulted
Brian DaSilva – Engineering Manager, CWSA, St. Vincent and the Grenadines.

Regional Workshop for the Wider Caribbean Region on Adopting, Applying and Operating Environmentally Sound Technologies for Domestic and Industrial Wastewater Treatment

Khansham Kanhai
Technical Adviser to the Minister of Public Utilities, Government of the Republic of Trinidad and Tobago

Introduction

In the modern world, the development of any country can be measured based on infrastructure, facilities and prevailing sanitary conditions. The standard of living of a country can be judged by the prevailing hygienic conditions, which in turn, are assessed on the level and quality of water supply and collection, treatment and disposal of liquid and solid wastes.

In Trinidad and Tobago, under the Water & Sewerage Act, 1965, the Water and Sewerage Authority (WASA) is responsible for both water supply and public sewerage systems. From 1965 to the present, the focus was mainly on expanding the potable water supply to meet the increasing demands of both domestic and industrial consumers, as attested to by the fact that approximately **95% of the country has access to a potable water supply, but less than 25% of the country has access to centralized sewerage systems.**

Initiatives In Water Sector Development

As opposed to the sewage sector, much progress has recently been made in the development of potable water supply systems. The large Industrial base in Trinidad and Tobago has perennially presented stressful demands on the existing water resources, and with the recent initiatives by Government to further encourage the expansion of the country's Industrial base, especially at the Point Lisas Industrial Estate, the water supply situation is expected to reach critical proportions by the year 2000.

In fact, there is a present water supply deficit of approximately 18 mgd in Trinidad and Tobago, and within the next 5 years or so, it is expected that this deficit will increase to approximately 39 mgd if no additional sources are developed. It is in this scenario that the Government, in consideration of the limited funding available, has embarked on a number of priority projects to concentrate on water supply rather than on the sewage sector. Some of these projects include the provision of some 20 mgd of additional potable water into the transmission and distribution system together with the installation of a desalination plant at the Point Lisas Industrial Estate dedicated to the Industrial consumers who are presently being charged a higher tariff than other consumers. All these initiative are targeted to be completed during the year 2000.

However, it has been recognized that the provision of water generates the production of sewage. With this in mind, the Government has also been actively preparing for the next stage in the development of the Water and Sewerage Sector to deal with issues relating to the maintenance and expansion of the existing sewerage system, constructing and developing new sewage works, adopting and rationalizing private sewage systems, and establishing the legal framework for control and monitoring of all wastewater systems in the future. The Environmental Management Authority (EMA) has been appointed by Government to establish and implement a Pollution Control and Monitoring Programme to ensure compliance by all owners and operators of wastewater treatment facilities.

History of Wastewater Sector

The first sewerage system in Trinidad was constructed in Port of Spain in 1861, and was progressively upgraded to serve areas immediately west of the capital city, i.e. Mucurapo and environs, until 1937. In 1965 however, the Government of Trinidad and Tobago undertook the largest single sewerage project in the country's history when the Port of Spain system was upgraded and extended to serve as far as Point Cumana in the west and San Juan in the east. This project also incorporated the construction of centralized sewerage systems within the then Boroughs of San Fernando and Arima.

In the last 30 years, the development of the sewerage sector has been virtually at a standstill. Besides the provision of sewerage services to the city of Scarborough in Tobago, no major development has taken place in the sewerage sector since 1965. This situation has generated major concern by the present Government and a Task Force has been appointed to develop a National Policy for the Wastewater Sector Development.

Existing Public Systems

Since the Authority was incorporated in 1965, growth within the public sewerage sector has been realized primarily through the adoption of seven (7) small private systems. **Currently the Authority owns and operates 12 wastewater systems - comprising 12 treatment plants and 22 pumping stations. These systems serve a population of approximately 250,000.**

The four urban centres at Port of Spain, San Fernando, Arima and Scarborough account for the majority (95%) of the wastewater generated within the public systems, while the remaining eight smaller systems account for a mere 5% of the total wastewater treated.

Over the years the collection systems, pumping stations and treatment plants have deteriorated to such levels that **major refurbishment works are required to restore satisfactory performance and reliability to these systems.** Current budget allocations do not support improvement works in the sewage sector since the concentration of efforts has traditionally been in the production of potable water to meet consumer demands.

Existing Private Systems

Considerable housing and industrial development has taken place over the last two decades and is continuing to take place in many areas of the country irrespective of the fact that the expansion of the existing network of centralized sewerage systems has not kept pace with this development. Developers therefore have been required to construct, operate and maintain their own private wastewater systems and this has resulted in the proliferation of numerous small private wastewater systems all over the country. This is clearly evidenced by the fact that the **estimated 150-odd private systems** (including those operated by state agencies such as the National Housing Authority) **serve a mere 10% of the population** of the country.

The operation and maintenance of these private systems has remained the responsibility of the respective owners and the recently concluded Adoption Strategy Study, occasioned by the Government and conducted by a joint GORTT/WASA/TTWS Team, is targeted to address the rationalization, adoption, maintenance and expansion of these systems.

Until this Strategy is implemented, the private owner/operator remains responsible for the operation and maintenance of the private wastewater system within the constraints of the Public Health Ordinance, Water and Sewerage Act, Environmental Management Act, and other relevant legislation.

Legal Aspects

It is noted that:

i. **Under Section 62** of the Water and Sewerage Act, Chapter 54:40, WASA is responsible for:

a. Maintaining and developing the existing sewerage system, and all sewerage works vested onto it,
b. Constructing and developing such further sewerage works as it considers necessary or expedient, and,
c. Administering the sewerage services, thereby establishing and providing sewerage facilities in Trinidad and Tobago.

ii. **Under Section 65** of the same Act, the Water and Sewerage Authority, by Order may divide Trinidad and Tobago into <u>sewerage areas</u> for inter alia:

- <u>Vesting in itself any sewerage works</u> constructed in such areas as well as the existing sewerage system

iii. **By Legal Notice No. 97 of 1987,** the entire country of Trinidad and Tobago has been divided into five (5) distinct sewerage areas:

- The Port of Spain Sewerage Area
- The San Fernando Sewerage Area
- The Arima Sewerage Area
- The Trincity Sewerage Area

- The entire country of Trinidad and Tobago excluding the Port of Spain, San Fernando, Arima and Trincity Sewerage Areas

Trade Effluent Discharges

The discharge of high-strength waste into the public sewers is a matter of concern to the Government and one which is to be addressed by the development of appropriate regulatory procedures, wastewater tariffs for trade effluent, as well as monitoring and control systems to manage this aspect of the Authority's operations.

Wastewater Tariff

Sewerage tariffs in Trinidad and Tobago are low both in absolute terms and relative to water supply charges. The rates charged for sewerage services are a poor reflection of the cost of providing those services.

In England and Wales, the tariff reflects the cost of provision of sewerage services and **the average sewerage tariff** (US$1.78/m_) **is more than the water supply tariff** (US$1.54/m_). **In Trinidad and Tobago, the reverse holds, as the sewerage tariff is only 50% or _ of the water supply tariff.**

The necessary funds will have to be provided to finance the development of Sewerage Sector. Such finance will have two (2) separate and distinct elements, namely:-

- Initial costs to provide infrastructure for new sewerage systems or expand/up-grade the existing sewerage systems and treatment plants

- Continuing funding (revenue) for the operation and maintenance of the various sewerage systems.

This requires the preparation of **a new and comprehensive wastewater tariff which** is **directly related to the true costs of sewerage and sewage disposal services.**

A recent study by the Government, engaging the services of the international firm of London Economics, has produced several recommendations for tariff increases and this is currently being reviewed prior to implementation.

Current Projects/Studies

A number of initiatives are currently being pursued by the Authority in an attempt to improve system performance, as briefly discussed below.

- **Water Supply and Sewerage Rehabilitation Projects (WSSRP)**

Works funded jointly by the World Bank (WB) and the European Investment Bank (EIB) totaling $21.3m have been proposed under this program for the complete refurbishment of 9 treatment plants and 21 pumping stations operated by the Authority. Actual construction work on this project is expected to start in early 1999, in accordance with current schedules.

- **Greater Port of Spain Sewerage System Study (GPOSSSS)**

A study funded by the Caribbean Development Bank valued at $7m to evaluate the Greater Port of Spain Sewerage System has been completed in September 1998 and is also under review prior to implementation. Due to the lack of funding and in consideration of the urgent need to improve the quality of effluent discharge from the main sewer treatment plant serving the area, Government is presently looking at the possibility of encouraging private sector participation for the development of the sector in the Greater Port of Spain Area.

- **Minor Projects/Studies**

    - A study funded by the Tobago House of Assembly and valued at $0.5m, aimed at developing proposals for the integration of the Signal Hill sewerage system into the existing Scarborough sewerage system, is currently underway.

    - Proposals to improve the existing wastewater systems within the South-West region of Tobago have been submitted by the Trinidad and Tobago Water Services (TTWS) on behalf WASA. **Preservation of coastal environment in Tobago as is relates to and affects recreation and the marine ecology with special reference to the Buccoo Reef reinforces the urgent need for the implementation of this project.**

    - **Emergency works** have been planned and capital funding has been requested against the following system components at **Beetham:**

        1. Force Main: to repair badly deteriorated 48" diameter pipes,
        2. Pumping Station: to upgrade mechanical, electrical and instrumentation equipment.

-

Adoption of Private Systems

As mentioned before, a strategy for the adoption of privately-owned wastewater systems has been prepared by the Trinidad and Tobago Water Services on behalf of the Government of Trinidad and Tobago and the Water and Sewerage Authority, and is currently engaging the attention of the Government.

Key Issues

1. **Need for a national wastewater policy.**

2. **Institutional strengthening of the Sewerage Sector in WASA.**

3. **Development of a Wastewater Master Plan for Trinidad and Tobago.**

4. **Policy on private wastewater systems in Trinidad and Tobago**

    - **for existing systems**
    - **for new systems**

5. **Development of regulatory and monitoring mechanisms to control the discharge of trade effluents in to the public sewers.**

6. **Implementation of appropriate wastewater/sewerage tariff for Public (WASA) & Private Wastewater Systems.**

7. **Provision of centralized sewerage systems at all urban centres and industrial estates.**

8. **Strategy to integrate smaller wastewater systems.**

9. **Funding.**

Major Policy Framework to Address Key Issues

The following actions have recently been instituted by Government to address the key issues discussed in the preceding section:

1. Appointment of a task force in May 1998 to develop a national policy for the wastewater (sewerage) sector development.
2. Institutional strengthening of the Sewerage Sector, funding for which is being pursued with the World Bank and the EIB.
3. Wastewater master plan for Trinidad and Tobago based on the recommendation of the Government appointed Task Force.

4. Review of wastewater/sewerage tariffs to appropriate levels with respect to:

    - Domestic wastewater discharges (tariffs should be at least equal to that of water), and
    - Trade effluent discharges.

5. Development of trade effluent discharge regulatory procedures and monitoring system to control trade effluent discharged into public sewerage systems being done by the EMA. The EMA to establish and implement a Pollution Control and Monitoring Programme to ensure the compliance by the private owner/developer of the wastewater system until such time that they are adopted by the Water and Sewerage Authority based on their technical and economical viability.
6. Establish a joint focus team of stake-holders to develop and agree on the action plan based on the TTWS final report on the adoption of private sewage treatment works (November 1997) on adoption of private wastewater systems.
7. Interim provision for private owner of wastewater systems to charge sewerage rates from the residents/users of these facilities once the owner efficiently operate and maintain the wastewater system and meet the effluent discharge conditions set by the EMA. This measure must be of a temporary nature and after a defined period, the Water and Sewerage Authority must accept the eventual responsibility for operating and maintaining these systems. The defined period will be determined by:

- WASA's adoption strategy and action plan, and

- EMA's advice based on the compliance of the discharge permit condition over a period.

Future Vision

The future vision in the wastewater sector in Trinidad and Tobago is to have centralized sewerage systems at all urban centres, industrial estates, suburban developments and village communities (representing approximately 90% of the population of 1.3M) efficiently operated, managed and maintained to satisfy environmentally-friendly effluent discharge standards, financially supported by sustainable tariff levels.

Deterrents to this vision have been principally identified as the shortage of funding and the urgent need to fast-track the legislative monitoring and control mechanisms.

However, the number of initiatives presently being undertaken by Government are geared towards surmounting these hurdles and achieving this vision, and have most certainly involved the adoption and application of environmentally-sound technologies for wastewater treatment.

Acknowledgements

1. Policy Paper for Wastewater/Sewerage Sector Development (May 1998) - M. Kerof
2. Status Report on Sewerage Sector in Trinidad and Tobago (June 1989) - D. Sharma, M. Kerof, A.S. Tota.
3. WASA Tariff Study Report (March 1998) - London Economics/Castalia
4. Adoption of Private Sewerage Treatment Works (1997) - GORTT/WASA/TTWS
5. Greater Port of Spain Sewerage System Study Report (September 1998) - Reid Crowther/Alpha Engineering.

Treatment of Wastewater Discharges to the Greater Caribbean Area

Louis Salguero
UNITED STATES OF AMERICA

Improving the water quality in the greater Caribbean area is a vision which can be made a reality through cooperation. The communities of the greater Caribbean area are connected physically to each other by water. This fluid of water provides for the economic, ecological, and spiritual benefit of all men. The Gulf of Mexico which embraces the Caribbean Sea is bordered by five North American states (Florida, Alabama, Mississippi, Louisiana, and Texas). The habitats and ecosystems along this American coastline are diverse and critical for helping to maintain the rich abundance of marine wildlife in the Gulf. Fresh water from the United States flows into the Gulf bringing nutrients and sediment to help feed these activities. The Mississippi River alone brings to Gulf 1.06 trillion cubic metres of fresh water. The Loop circulates the waters of the Gulf starting from the Yucatan Strait and existing through the Straits of Florida. To protect this fragile environment in 1988 the Federal Government, the Gulf States, business, industries, non-profit organizations, educational institutions, and other interested stakeholders joined forces to form the Gulf of Mexico Program. This program raised environmental protection to a new level of multi-involvement and cooperation in the United States. As members of the Greater Caribbean community the United States also wants to participate in making the vision of improving water quality in the Caribbean Sea a reality.

The first step in protecting these waters has been made possible as a result of technological breakthroughs in communication. And that step is awareness. Awareness that the environment is a living global entity that can only be protected through the cooperation of all people and all governments. Vast amounts of environmental information can now be accessed on the Internet to drive this awareness.

I would like to talk about the wastewater problems of the Central American region and appropriate wastewater technologies needed to solve them. Through an interagency agreement US-AID and the US-EPA are providing technical assistance tot he Central American countries in addressing their environmental problems. I have traveled to several Central American countries to view the wastewater problems of the region. The wastewater problems faced by these countries are great but not insurmountable. The developing countries most find appropriate solutions that are low in cost and that use technologies that are simple to operate. Low in cost not only in initial installation but in operation. Activated sludge wastewater treatment plants are high in energy consumption and thus invite high energy cost. There may be situations where an activated sludge system is necessary but other appropriate and alternative wastewater treatment systems should be evaluated.

Presently, wastewater from most industries and municipalities in the region are not receiving any wastewater treatment. Municipal discharges to receiving streams are high in BOD, TSS, fecal coliform, and nutrients. These receiving streams eventually flow into either the Pacific Ocean or the Caribbean Sea. In addition, there are direct discharges to the Caribbean Sea from port towns. One of these towns that I am working with is Puerto Barrios in Guatemala.

Slide Presentation Starts:

The people of Puerto Barrios have asked for help in solving their wastewater problem. The problems are septic discharges to rivers that flow through the town into the Gulf of Honduras. There is no sewer collection system in the town and open ditches are used to collect wastewater. The ditches are flushed only during storm events. To complicate the situation the ground water table in some cases is only centimetres from ground level. Traditional collection systems would be very expensive to install.

A pilot project is being proposed where a small diameter collection system will be used to transport the filtrate from septic tanks in a one block area to a main collection tank for pumping. The pumped wastewater will be treated in an recirculating sand filter. Treated effluent from the sand filter will then be discharged to the Rio Escondido.

Slides of Appropriate Technologies:

At this point, I would like to show slides of some appropriate technologies for developing countries:

- Rich Lagoon System
- Sand Filters
- Alternative Collection Systems
- Sand Filters used in the State of Tennessee
- Water Tight Septic Tanks
- Slow-rate Trickling Filters

Adopting, Applying and Operating Environmentally Sound Technologies for Domestic and Industrial Wastewater Regional workshop for the Wider Caribbean Region

Fanny Rodríguez
VENEZUELA

Introduction

The Ministry of Environment and Natural Renewable Resources is uncharged for deciding rules about defense, conservation and improvement of the area that includes Lake Valencia Basin, of executing researches, Studies and projects and building sanitary infrastructure needed for giving a solution to the environmental problem in this basin, one the most populous area in the country.

The increase of population till 2.5 millions people (13% of all the country) joined by the fast expansion of industry (30% of all the country) and agriculture has provocated a very high degradation in this basin and for this reason the Venezuelan Government, conscious of this problem has been working during the last years, through the Ministry of Environment and Natural Renewable Resources, in various studies about the Lake Valencia with the purpose of identifying the problems in the Lake Basin, for obtaining necessary knowledge that will bring concrete information for action policy formulas to correct or control pollution situations that appears in this important water reserve and his basin, preventing actually any kind of use.

Results of this work is the basic purpose of obtaining the Lake Valencia Sanitation as well as his affluents, with the actual construction of the following waste water treatment systems:

La Mariposa and Los Guayos on the Valencia - Guacara Zone.
Taiguaiguay on the Maracay Zone.

Lake Valencia is one the greatest water bodies in the northern part of South America, it covers an approximate area of 350 square kilometers and receives water from several rivers.

The most pollution levels are present in areas under direct influence of rivers that drain the principle urban and industrial zones.

Sources and type of pollution:
The wastewater effluent can be categorized according to their sources:
-Domestic Effluents
-Industrial Effluents
-Livestock activities
-Agriculture activities

Industries in the Catchment Area

Primary Industry: Sugar cane, fruits, vegetables, cattle rising.

Secondary Industry: Metallurgy, oil and deviates, paper and cellulose, chemical and agrochemical, nourishing, alcoholic and non alcoholic beverages.

Tertiary industry: Financial activities, government's activities, and commercial activities.

For regulation this activities was established Decree Nº 883. The present Decree establish the norms for the control of the quality of the bodies of water and poured liquids, published in official Newspaper Nº 5021, dated 1985.

Project of the System for the Treatment of Residual Waters in the Basin of the Lake Valencia

Having concerned with such environmental problem of the Lake ,the Government has been undertaking several series of investment, studies and projects related with water quality improvement, flood control and water transfer- supply under the Integral Program for Environmental Improvement of the Basin of Valencia Lake. Above all, the lake basin sewage system with there wastewater treatment plants has been developing, supported financially by IDB (Inter American Development Bank). This sewage system is expected to be operated within few years and contributed to improve water quality of the lake, eliminating more than 90% of organic pollutants flowing into the lake.

Conceptualization of the Project

The execution of the project will eliminate 90% of the contamination of the waters of the lake caused by:

- Intensive industrialization in the basin.
- The rivers flow toward a closed valley.
- Natural drainage transport waste, which end up in the lake.
- A floweret of 6,7 m^3 /s from municipal waters not treated are discharged directly into the lake.
- The lake behave like a biological reactor ,where biodegradable residues are consumed and the non biodegradable are transformed in solutions or silt.

The program contemplates specific projects in the following stages:

- Project. Supply of drinkable water for the population in the basin.
- Project Treatment System for served water from domestic and industrial use.
- Project Control the level of lake and contraction of pluvial drainage and special financement studies.

Complementary Activities:

- Program to control industrial effluents, Ordinances 883 and environmental Penal Law.
- Fare Study and Methods of Controlling Industries Effluents.
- Training Program for professional personnel for the maintenance and operation of the treatment plants.
- Study the project for 3rd, stage which will allow to determined the factibility and convenience of doing this work and control it, like :

Factibility study and the design of treatment system of residual water for la Victoria and Guigue cities.

a. Factibility study and the design of works for an intensive development of la Cienaga del Paito area.
b. A non punctual contamination study due to agricultural activities.
c. Contamination study and over exploitation of under ground waters of basin.

Additional gain:

- The recollection work and treatment proposal, will reduce the volumes of water dump into the lake, reusing about 3.8m3/s for irrigation in the East side and 2.4 m3/s for irrigation in the West side.
- The project will contribute to diminish the average ascend of the lake, from 43 cm to 11 cm per years and the progressive recuperation of the aquifers that are overuse at the present.
- Concerning irrigation, it is estimated that in the Taiguaiguay area, 5400 hectares will be irrigated with treated water from the city of Maracay.
- Depending on the degree of recuperation of the lake Valencia, we hope to be able to use the water as a source for human consumption from the Central Region and Metropolitan Area of Caracas.

Socio-Economical Justification of the Project:

- The project provides primary collectors and treatment plant to the present local sewage system in urban areas of Maracay and Valencia cities.
- The project allows the use of treaties effluents for irrigation.
- It will contributed to diminish the rate of ascend of the level of the lake.
- The recommended solution and presented in this proposition is MINIMUM ECONOMICAL COST, TECHNICALLY POSSIBLE.

Additional Benefits:

- Reduction of use of under ground water for irrigation in the basin.
- Reduction of possibilities of infrastructure loss due to subsidence of the land, and over exploitation of aquifers.
- The lake could be used for urban supply, mix with other sourcer.

- The possibility of introduce commercial fish farming.
- The use of treated serve water, which are rich in phosphorus and nitrogen, will save in the in use of fertilizers .

Payment Capacity:

Only 1% of the families living in the area will compromise 3% of their earnings, for the payment of potable water and sewage system combined.

Maracay System

Near Maracay, there is reservoir feeding an extensive irrigation system which is underused due to lack of water. To remedy the water shortage, the city is intercepting sewer will terminate in a central pumping station from which screened and degraded sewage will be pumped through a 1.80 rising main 17 Km to lagoon system with a stage 1 mean design flow of 5 m3/s built on public land on the Northern edge of the reservoir.

Sewage from the towns of Cagua and Turmero will join the inlet channel of the lagoon system.

The lagoon system will consist of four anaerobic reactors of one day retention time followed by a facultative lagoon of 5 days detention time before discharge into the irrigation reservoir. The reservoir will store the effluent during the rainy season for release for irrigation during the dry season (December-May). In this way, effluent discharge to the lake from the Maracay area will be reduce practically to zero until the peripheral aquifer recuperate. Recycle from the facultative lagoon will be used to raise the pH and reduce odors from the anaerobic reactors.

Valencia System

The sewage from the Eastern, predominantly industrial, areas of Valencia will be carried to the Los Guayos lagoon system, described previously of 2 m3/s mean design flow and used for irrigation during the dry season. During the wet season the effluent will discharge to the lake.

The sewage from the central and Western, primarily domestic and commercial areas of Valencia will be conveyed to the Mariposa treatment plant used for irrigation in the dry season. In the wet season, the effluent will be discharged to the Pao river system as planned indirect reuse. The Pao dam is eutrophic due to diffuse nutrient sources from agriculture and uncontrolled sewage recycle. This make its water odorous and difficult to treat for potable use because of large numbers of Naviculas which reduce filter runs to as little as 6 hours at times.

The Mariposa plant will therefore be more advanced than the other treatment system and will employ biological nutrient removal, tertiary filtration and polishing in a natural wetland.

The plant will consist of four treatment modules each for 200.000 population equivalents and 600 l/s mean design flow each, based on modification of the activated sludge process, followed by rapid gravity filtration to remove residual solids bound phosphorus and also to act as barrier to helminthes and protozoa cysts. Waste sludge will be thickened by gravity and dried in lagoons, stored for one year and them, subject to heavy metal content, be used in agriculture.

Artificial disaffection such as chlorination has not been envisaged in order to permit maximum natural biodegradation and removal of pathogens in the 20 Km marsh and natural river course between the plant out fall and the Pao dam.

A number of details of plant have been simplified in line with prevailing human resource limitations. The screens will be manually raked; the aerator will be high speed direct drive bridge mounted and sophisticated control system will be kept to a minimum. The filters will be of the declining rate, declining level self backwashing type, reducing the number of valves to only two per filter.

Environmental Education

Concerted efforts are carried out by both Government and the citizen in a necessity for proper Lake Valencia Basin development. It is therefore very important educate the citizen on the Lake Environmental Problems.

Lake Valencia has a great natural beauty, but it is not well know. Implementation of environmental education programs in the formal education is necessary, because the Lake Valencia is still considered by most of community like an enormous open sewer.

Is of big importance the diffusion in the Regional television, campaigns of environmental preservation altogether with education, participation and relation with usurious management of Lake Valencia Basin.

Conclusion and Recommendations

The big problem in the Central Region of country is the Lake Valencia Eutrophication, by pollution of water of its tributaries rivers.

The Project of System for the Treatment of Residual Water in the Basin of Lake Valencia is the key for to improve water quality of the lake but it is only the beginning, in consequence, according to the current state of the Lake, it is necessary to make a more exhaustive study for what is recommended:

- To continue the studies of physical – chemical parameters in integral and systematic form of the water of the lake.

- To carry out a fish study, as for changes of diversity and content of accumulative substances

- To determine the concentration and distribution of toxic organic substances and heavy metals in the water and sediments.

- To carry out measurements of the speed and direction of the movement (current) of water, to understand the diffusion process that affects the distribution of polluting substances in the lake.

- To continue with the study of identification of phitoplancton and zooplancton .

- To continue with the study of bentic organism in sediment of the lake, due to being indicator of quality of the water.

- To make a study of punctual and non punctual sources of the basin that discharge into the lake and they have not been studied.

- To determine the concentration of atmospheric pollutant in the rain water and their influence in the lake.

We must to have in consideration that when the project is completed, Lake Valencia water will only be used for irrigation subject to improvement over the years. Constant monitoring of the water quality, sediments and biota will be carried out to assess when it will become suitable for domestic use. This can occur in 10,20 or 30 years time.

PART 3

GROUP DISCUSSION

Table of Issues, Existing Technologies and Future Possible Options

The final session was a Group Discussion to develop action plans for the future. Four groups separately listed the issues, existing technologies and future possible options in their countries. Each group was given three (3) stickers for three (3) former categories. Each group then rated each entry for its priority or prevalence by placing three (3) stickers on their chosen entries. The numbers after each line item represents the summation for the group (i.e. the higher the number the higher the priority or prevalence). The following tables document the results of these group discussions.

GROUP 1

PARTICIPANTS:

Anguilla:	*Mr. Stephenson Rogers*	St Kitts & Nevis:	*Mr. Errol Rawlins*
Antigua & Barbuda:	*Mr. David Mattery*	St Lucia:	*Ms Francine Clouden*
Barbados:	*Mr. Anthony S Headley*	St Lucia:	*Mr. Errol Frederick*
France:	*Mr. Eric Muller*	Trinidad & Tobago:	*Mr. Kansham Kanhai*

Facilitator: Assoc. Prof. Goen Ho, Australia

ISSUES	EXISTING TECHNOLOGIES	FUTURE
Marine pollution (7) Lack of legislation and standards (4) Training of personnel (4) Lack of maintenance (3) Lack of enforcement/ management (3)	<u>COLLECTION</u> Pit latrine (6) Night soil (1)	<u>COLLECTION</u> More central sewerage (with treatment) (6) Training and public education (4) Rationalisation of existing system (2) Small bore sewerage (1)

<table>
<tr>
<td rowspan="2">Lack of funding (2)

Lack of education (public) (2)

High level of nitrates (aquifer) (1)

Management of night soil (1)

Lack of institutional frameworks

Limited land space

High water table

Appropriate tarn-f structure

Lack of monitoring/data

Improper effluent disposal (st)

Sewage management outside sewered areas

Lack of regional policy

Laboratory accreditation

Water scarcity/regular supply</td>
<td><u>TREATMENT</u>

Septic tank (10)

Packaged treatment plant (6)

Activated sludge (2)

Grease trap (1)

Ponds (1)

Filter bed</td>
<td><u>TREATMENT</u>

Improved on-site system (9)</td>
</tr>
<tr>
<td><u>DISPOSAL</u>

Aquatic

No treatment

Marine outfall (no treatment)</td>
<td><u>DISPOSAL</u>

Reuse and recycle (5)</td>
</tr>
</table>

GROUP 2

PARTICIPANTS:

Aruba	*Mr. Elton Lioe-A-Tjam*	Jamaica	*Mr. Donald McDowell*
Bahamas	*Ms Christal Francis*	Jamaica	*Mr. Errol Motley*
British Virgin Island	*Mr. Mukesh Ganesh*	Jamaica	*Mr. David Steen*
Haiti	*Pierre Carlo Lafond*	Netherlands Antilles	*Mr. Patricio D Oleana*
Jamaica	*Mr. Bruce Excell*	Netherlands Antilles	*Mr. Arthur Rodriguez*
Jamaica	*Ms Stephanie Fletcher*	Trinidad and Tobago	*Mr. Kansham Kanhai*

Facilitator: Dr Kuruvilla Mathew, Australia

<table>
<tr><th>ISSUES</th><th>EXISTING TECHNOLOGIES</th><th>FUTURE</th></tr>
<tr><td rowspan="3">Maintenance (5)

Enforcement of legislation (5)

Finance (5)

Upgrade and improvement (5)

Planning for future (4)

Pollution of coastal waters (3)

Lack of resources (1)

Integration of management policies (1)

Land availability (1)

Training of operators

High water consumption (conservation)</td><td>COLLECTION

Pit Latrines (2)

Community pit latrines (1)

Aqua – privy</td><td>COLLECTION

Sewer system (4)

Small diameter systems with effluent reclamation (2)

Pit Latrines (sanitary VIDP) (1)</td></tr>
<tr><td>TREATMENT

Septic tanks (8)

Lagoons (5)

Oxidation ditch (4)

Activated sludge system (4)

Trickling filter (2)

Package plants (2)

Sludge digestion

Sand filters

Botanic (aquatic)</td><td>TREATMENT

Activated sludge (8)

Septic tanks (5)

Wet lands (4)

UV Disinfection (3)

Lagoons (3)

Oxidation Ditches</td></tr>
<tr><td>DISPOSAL

Sea outfall (1)

Bag disposal method (1)

Ground infiltration</td><td>DISPOSAL

Small diameter systems with effluent reclamation (2)</td></tr>
</table>

GOALS		ACTION
1 2 3 4 5 6 7	Conventional pit latrines should be discouraged Rehabilitation Awareness – Education of policy marers as well as decision marers Sectoral approach – master plan Achievable goals – time limits Monitoring Enforcements of international treaties: - facilities need to be in place for ships to discharge in harbour Vessels should have holding tanks	Set goal for improvement of systems/areas to be covered in timeframe. Community Awareness – incorporate social and cultural activities. Associate with NOWRA Training and education: - user friendly; communication to owners; should be able to adopt as own system. - maESTro – to be encouraged Regional coordination program

GROUP 3

PARTICIPANTS:

Cabo Verde	*Mr. Antunio Barbosa*	Jamaica	*Mr. Matthew Krachon*
Canada	*Mr. Jean-Pierre Dube*	Jamaica	*Mr. Cliff Reynolds*
Canada	*Mr. John A McKee*	Jamaica	*Mr. Roger Surtees*
Canada	*Ms Christiane Roy*	USA	*Mr. Ted Loudon*
Jamaica	*Mr. Peter Collins*	USA	*Mr. David Pask*
Jamaica	*Ms Ining Hsu*		

Facilitator: Ms Christiane Roy, Canada

<table>
<tr><th>ISSUES</th><th>EXISTING TECHNOLOGIES</th><th>FUTURE</th></tr>
<tr><td rowspan="2">Political Will (10)
Education (5)
Money – Capital (4)
- O & M (4)
Cultural values (4)
Legal framework (3)
Management (2)
Public health (2)
Training (1)
Motivation (1)
Enforcement (1)
Standards
Monitoring
Technology perceptions
Public awareness
Natural resources
Subdivision practices
Social issues
Affordability</td><td>COLLECTION
None (6)
Septic tank effluent (3)
Municipal gravity sewer
Septage haulind
Surface/Gulleys
Gravity</td><td>COLLECTION
Rehabilitation (3)
Easily upgradable (3)
STEP and STEG (3)
Assistance in connection (2)
Water segregation (1)
On-site
No dig
Cluster
Extension of existing system
Standard gravity</td></tr>
<tr><td>TREATMENT
Lagoons (4)
None/Honey bags (3)
St & Absorption pits (1)
VIDP
VIP
Package plants
Activated sludge
Reed beds
Sand filters
Recir. Filter</td><td>TREATMENT
Low Tech (RSF, ISF, reed beds, Lagoons) (8)
Upgrading (1)
VIDP and others (1)
Tertiary (N.P. Disinfection) (1)
Standardization
Community
Maintenance
Rehabilitation
On-site</td></tr>
</table>

	DISPOSAL Sea outfall (8) Reuse (3) Soak away pits (2) Deep well injection Inland rivers Surface disposal	DISPOSAL Reuse water (7) Irrigation (1) Offshore disposal (1) Reuse sludge Groundwater recharge Soil conditioning
	EDUCATION PHASE	**PLANNING PHASE**
GOALS	Involve private sector early Academics involved in R.B.A. and continuing education Money: -perhaps funding from private/commercial (make it a business) - creative financing Emphasize the cultural values/issues Simultaneous action at political and community level Project management beginning to end Focus on practical action (deliverables) Not a handout – system controlled by people	Must continually assess effectiveness of education phase Technically part of planning phase must follow education phase and utilize its results Plan for O & M -- training -- funding Accountability Creative financing

<u>ACTION</u>	Risk based assessment Initial survey (person to person) - current situation (1) - public opinion (3) Develop education strategy (based on survey Technical workshops: - Government - Professionals - Consultants - Social works - Industry - NHO's Educate Public – Political Action	Some assessment of R.B.A initial solutions: - eliminate infeasible solutions - leadership development - community leaders (and therefore continuous feedback) Arise from Technical Workshops: - goals - priorities - means - action Critical Path Diagram

GROUP 4

PARTICIPANTS:

Belize	*Mr. Jose Medoza*	Mexico	*Dr Felipe Cortes*
Colombia	*Dr Serigo Cruz Fierro*	USA	*Mr. Louis Salguero*
Cuba	*Ms Carmen C Berro*	Venezuela	*Ms Fanny Rodriquez*
Guatemala	*Mr. Adan Collazos*		

Facilitator: Dr Martin Anda, Australia

ISSUES	**EXISTING TECHNOLOGIES**	**FUTURE**
Operation of management (4) Lack of financial resources (8) Capacity building (3) Political will (3)	<u>COLLECTION</u> Latrines (2) Dry toilets	<u>COLLECTION</u> Simplified collection systems (1) Collection systems w/minimal leakage (1) Small diameter pipes

Lack of plan (development) (2) Inappropriate technology (1) Multisectoralism Training Sensitive ecosystem	TREATMENT Stabilization pond (10) Trickling filters (4) Septic tanks (3) Imhoff tank (1) Tertiary treatment (1) Wetlands UASB – Unit Anaerobic Sludge Blanket Aerobic/Anaerobic ponds	TREATMENT Environmentally friendly systems of reasonable cost to all sectors (4) Appropriate legislation – monitoring and enforcement (4) Technology to remove industrial pollutants (pre-treatments) (3) Research and development of possible treatment options (2) Rehabilitation of existing systems (1)
	DISPOSAL Ocean outfall	DISPOSAL Recycle and reuse of wastes (5)
	GOALS	**ACTIONS**
ISSUES Lack of Financial Resources Operation and Management Capacity Building Political Will	Obtain Financial Resources Institute an Action Plan for a proper implementable Operation and Management System Institutional Strengthening Public Awareness	Debt Relief for Environment Protection. Charge consumer for wastewater: - Training - Networking of other Institutions Training Meetings/Conferences for Politicians
EXISTING SYSTEMS Stabilization of Ponds Trickling Systems Septic Tanks	Improve on Existing Systems	- Rehabilitation and Monitoring - Pilot Projects

FUTURE	Increase the amount and quality of available H_2O supply Develop appropriate laws and regulations to protect water bodies Network with other organizations of acquisition of appropriate technology	Education of Public and Cost Watershed Protection Workshop/Seminars with relevant organizations, etc

APPENDIX 1

PROGRAM

PROGRAM

Monday 16 November

8:30 a.m.		**Registration**
9:00 a.m.		**Welcome** *UNEP-CAR/RCU* **Introduction** *Mr. Vicente Santiago Fandino, IETC and Tim Kasten, CAR/RCU* **Introduction of Participants and Presenters**
10:30 a.m.		**Coffee Break**
11:00 a.m.	***Session 1:***	**Technology Choice and Sustainable Development** *Mr. Martin Anda, Murdoch University*
12:00 a.m.	***Session 2:***	**Development of a Protocol to Control Land-based Sources of Marine Pollution** *Mr. Tim Kasten, CAR/RCU*
12:30 p.m.		**Lunch**
1:30 p.m.	***Session 3:***	**Principles of Wastewater Treatment** *Associate Professor Goen Ho, Murdoch University*
2:30 p.m.		**Coffee Break**
3:00 p.m.	***Session 4:***	**Field Trip to Montego Bay Wastewater Collection and Treatment System**
5:00 p.m.		**Return to Hotel and Adjourn**
7:00 p.m.		**Cocktail Reception at Hotel**

Tuesday 17 November

9:00 a.m.	***Session 5.1:***	**Country Presentations from Delegates** *Moderator: Murdoch University* **Status of Wastewater Treatment Needs and Existing Technologies for Large Communities: Technology Barriers and Recommendations** ***Summary of Existing Technologies and Future Options*** *Dr Arreguin Cortes, Mexico* *Mr. Louis Salguero, USA* *Mr. Carlo Lafond, Haiti*
10:30 a.m.		**Coffee Break**
11:00 a.m.	***Session 5.2:***	**Country Presentations from Delegates** Moderator: *Murdoch University* **Status of Wastewater Treatment Needs and Existing Technologies for Large Communities: Technology Barriers and Recommendations** ***Summary of Existing Technologies and Future Options*** *Mrs. Ianthe Smith, Jamaica* *Mr. Kancham Kanhai, Trinidad & Tobago* *Mr. Brian George, St Vincent & The Grenadines*
12:30 p.m.		**Lunch**
1:30 p.m.	***Session 6:***	**Impacts of Organic Waste on the Marine Environment** *Ms Christine Gault, National Estuarine Research Reserve, Waquoit Bay, Massachusetts, USA*
3:00 p.m.		**Coffee Break**

3:30 p.m.	*Session 7:*	**Wastewater Collection and Treatment Systems for Large Communities in the Wider Caribbean** *Mr. Mark Lansdell, Mark Lansdell & Associates, Caracas* *Mr. Adan Pocasangre Collazos, CONAMA, Guatemala*
5:00 p.m.		**Adjourn**

Wednesday 18 November

9:00 a.m.	*Session 8:*	**Country Presentations from Delegates** *Moderator: Murdoch University* **Status of Wastewater Treatment Needs and Existing Technologies for Medium and Small Communities: Technology Barriers and Recommendations** ***Summary of Existing Technologies and Future Options*** *Mrs. Carmen Terry Berro, Cuba* *Ms Christal Francis, Bahamas* *Mr. Arthur Rodriguez & Mr. Patricio Oleana, Netherlands Antilles*
10:30 a.m.		**Coffee Break**
11:00 a.m.	*Session 9:*	**Small Community Wastewater Treatment Systems** *Ms Christiane Roy, Options Environment Inc., Montreal, Canada* *Ms Francine Clouden, Caribbean Inst. of Environmental Health, St Lucia*
12:30 p.m.		**Lunch**
1:30 p.m.	*Session 10:*	**Decision-making Software and Information Systems** **"maESTro"** *Mr. Vicente Santiago Fandino, IETC* **"WAWTARR"** *Mr. Chris McGahey, Vermont, USA*
3:00 p.m.		**Coffee Break**
3.30 p.m.	*Session 11:*	**Field Trip – On-site Wastewater Treatment System**
5:00 p.m.		**Return to Hotel and Adjourn**

Thursday 19 November

9:00 a.m.	*Session 12:*	**Treatment of Organic Waste from Industrial Facilities** *Ms Julia Brown, Integrated Waste Water, Kingston, Jamaica* *Mr. John A McKee, OMM Trow Consulting Engineers, Ontario, Canada*
10:30 a.m.		**Coffee Break**
11:00 a.m.	*Session 13:*	**Country Presentations from Delegates** *Moderator: Murdoch University* **Status of Wastewater Treatment Needs and Existing Technologies for On-site and Household Systems: Technology Barriers and Recommendations** ***Summary of Existing Technologies and Future Options*** *Mr. Errol Frederick, St Lucia* *Mr. Mukesh Ganesh, British Virgin Islands* *Mr. Anthony Headley, Barbados*
12:30 p.m.		**Lunch**
1:30 p.m.	*Session 14:*	**On-site Systems** *Mr. David Pask, Small Flows Clearinghouse, USA* *Mr. Antunio de Cassia Sousa Babosa, Director of Ports and Marinas, Cape Verde*
3:00 p.m.		**Coffee Break**
3:30 p.m.	*Session 15:*	**Household Systems for Wastewater Treatment** *Dr Kuruvilla Mathew, Murdoch University* *Professor Ted Loudon, Michigan State University, USA* *Mr. Stephen Hodges, Construction Resource and Development Centre, Jamaica*
5:00 p.m.		**Adjourn**

Friday 20 November

9:00 a.m.	***Session 16:***	**Group Discussion on Environmentally Sound Technologies** *Moderators*: Murdoch University and CAR/RCU
10:30 a.m.		**Coffee Break**
11:00 a.m.	***Session 17:***	**Evaluation, Feedback, and Future Direction** *Moderators: ITEC, CAR/RCU and Murdoch University*
12:30 p.m.		**Group Lunch** *Presentation of Certificates* *Closing Remarks: IETC and CAR/RCU*
2:00 p.m.		**End of Workshop**

APPENDIX 2

LIST OF RESOURCE TEAM

AUSTRALIA

Mr. Martin Anda
Murdoch University
Environmental Science
Murdoch WA 6150
Australia

Tel: (61-8) 9360-6123
Fax: (61-8) 9310-4997
Email: anda@essun1.murdoch.edu.au

Mr. Goen Ho
Murdoch University
Murdoch WA 6150
Australia

Tel: (61-8) 9360-2167
Fax: (61-8) 9310-4997
E-mail: ho@essun1.murdoch.edu.au

Dr Kuruvilla Mathew
Environmental Science
Murdoch University
Murdoch WA 6150
Australia

Tel: (61-8) 9360-2896
Fax: (61-8) 9310 4997
Email: mathew@essun1.murdoch.edu.au

CABO VERDE

Antunio de Cassia Sousa Barbosa
Director
Directorate General of Marine Affairs
PO Box 7
S. Vicente
Cabo Verde

Tel: (238) 324-342
Fax: (238) 324-343
Email: dgmp@milton.cvtelecom.cv

CANADA

Mr. John A McKee
Oliver, Mangione McCalla
154 Colonmade Road South
Nepean, Ontario
Canada K2E7J5

Tel: (613) 225-9940 ext. 241
Fax: (613) 225-7337
Email: omm@trow.com

Ms Christiane Roy
Option Environment Inc
2360 Avenue de La Salle
Bureau 202
Montreal, Quebec H1V 2L1
Canada

Tel: (514) 257-6380
Fax: (514) 257-6382
Email: croy@opt-env.qc.ca

GUATEMALA

Adan Ernesto Pocasangre Collazos
Executive Director of the Liquid and Solid Wastes Council
Conama
7a Ave. 7-13 Zona 13
Guatemala, Guatemala

Tel: (502) 440-7916/17
Fax: (502) 440-7938
Home Tel/Fax: (502) 474-3601

JAMAICA

Ms Julia Brown
Integrated Wastewater
Management Project
Scientific Research Council
Hope Gardens
PO Box 350
Kingston 6, Jamaica

Tel: (876) 927-1771 to 4 ext. 3102
Fax: (876) 977-2194
Email: icomppm@cwjamaica.com

Mr. Stephen Hodges
Construction Resource and Development Centre
11 Lady Musgrave Avenue
Kingston 10
JAMAICA

Tel: (876) 978-4061
Fax: (876) 978-4062
Email: crdc@jol.com.jm

Mr. Tim Kasten
Programme Officer
UNEP-CAR/RCU
14-20 Port Royal Street
Kingston
Jamaica

Tel: (876) 922-9267-9
Fax: (876) 922-9292
Email: tjk.uneprcuja@cwjamaica.com

JAPAN

Vicente Santiago Fandino
Programme Officer
Shiga Office
1091 Oroshimo-cho, Kusatsu City
Shiga 525-0001
Japan

Tel: (81-77) 568-4585
Fax: (81-77) 568-4587
Email: vstiago@unep.or.jp

ST LUCIA

Ms Francine Clouden
Caribbean Environmental Health Institute (CEHI)
PO Box 1111
The Morne
Castries
St Lucia

Tel: (758) 452-2501
Fax: (758) 453-2721
Email: fclouden.cehi@candw.lc

UNITED STATES OF AMERICA

Ms Christine Gault
Waquoit Bay National Estuarine
Research Reserve
PO Box 3092
Waquoit, MA 02536

Tel: (508) 457-0495 ext. 101
Fax: (617) 727-5537
Email: cgault@capecod.net

Mr. Ted Loudon
Agricultural Engineering Department
Farrall Hall
Michigan State University
Farrall Hall
E. Lansing, MI 48824
USA

Tel: (517) 353-3741
Fax: (517) 353-8982
Email: loudon@egr.msu.edu

Mr. Chris McGahey
Associates in Rural development Burlington,
Vermont
USA

Fax: 802-658-3890
Fax: 802-658-4247
Email: cmgahey@ardinc.com

AND

USAID CWIP
5 Oxford Park Avenue
Kingston
Jamaica

Tel: (876) 754-3910/2

Mr. David Pask
National Small Flows Clearing House
PO Box 6064
West Virginia State University
Morgantown, WV 26506-6064
USA

Tel: (304) 293 4191 ext. 5516
Fax: (304) 293 3161
Email: dpask@wvu.edu

FIELD TRIP/TOUR GUIDES

Session 4

Mr. Andrew JJ Burrow
DHV International

Tel: (876) 940-3423/4447
Fax: (876) 940-2619
Email: burrow@cwjamaica.com

Session 11

Ms Heather McFarlane
Construction Resource and Development Centre

Tel: (876) 940-2933-4
Fax: (876) 940-2935
Email: crde@jol.com.jm

Session 11

Ms Karen Michell
Sanitation Support Unit
Paradise Norwood
PO Box 417
Montego Bay
St James

Tel: (876) 940-2933-4
Fax: (876) 940-2935
Email: crde@jol.com.jm

APPENDIX 3

LIST OF COUNTRY REPRESENTATIVES

ARUBA

Dr Ing. Elton L. Lioe-A-Tjam
Director
Directorate VROM
Government of Aruba
Wayaca 31-C
Oranjestad
Aruba

Tel: 297-832345
Fax: 297-832342
Email: vromaua.dir@setarnet.aw

BAHAMAS

Ms Christal Francis
Water & Sewerage Corporation
PO Box N-3905
Nassau
Bahamas

Tel: 242-323-7474 ext. 5738
Fax: 242-322-5080

BARBADOS

Mr. Anthony S. Headley
Acting Deputy Chief
Environmental Engineer
Environmental Engineering Division
Ministry of Health & Environment
Culloden Farm, Culloden Road
St Michael
Barbados

Tel: 246-436-4820/6
Fax: 246-228-7103
E-mail: msquared@surf.com

BELIZE

Mr. Jose Mendoza
Environmental Officer
Ministry of Natural Resources and the Environment
Department of the Environment
10/12 Ambergis Avenue
Belmopan, Cayo District
Belize

Tel: 501-8 22816/22542
Fax: 242-322-5080
Email: envirodept@btl.net

BRITISH VIRGIN IS LANDS

Mr. Mukesh Ganesh
Engineer
Water & Sewage Department
Min. of Communications & Works
PO Box 130
Roadtown, Tortola
British Virgin Islands

Tel: 284-494-3416/7 ext. 5797
Fax: 284-494-6746
Email: water@caribsurf.com

COLOMBIA

Dr Serigo Alberto Cruz Fierro
Funcionario
Direccion Tecnica de Desarrollo Sostenible
Ministerio del Medio Ambiente
Calle 37 No. 8-40
Santafe de Bogota
Colombia

Tel: 57-1 338-3900 ext. 430-429
Fax: 57-1 288-9725
Email: cruzser@hotmail.com

CUBA

Ms Carmen C Terry Berro
Specialist
Environmental Agency
Ministry of Science, Technology and Environment
Calle 20 Esquina 18A
No. 4110, Playa
Ciudad de la Habana
Cuba
Tel: 537-229351/296014
Fax: 537-249031
Email: cterry@cigea.unepnet.inf.cu

HAITI

Pierre Daniel Carlo Lafond
Directeur General
Ministere de L'Environnenment
181 Haut Turgeau
P-AU-P
Haiti

Tel: 509-45 0635/45 7585/45 7572
Fax: 509-45 7360/45 1022
Email: dg.mde@rehred.haiti.net
Email: dg.mde@palaishaiti.net

JAMAICA

Mrs Ianthe Smith
Senior Director
Pollution Control
Natural Resources Conservation Authority
53 1/2 Molynes Road
Kingston 10
Jamaica

Tel: 876-923 5125
Fax: 876-923 5070

MEXICO

Dr Felipe Arreguin Cortes
Coordinador
Tratamiento y Calidad de Agua
Instituto Mexicano de Tecnologia del Agua
(IMTA)
Paseo Cuauhuahuac 8532
Jiutepec, Morelos, C.P. 62550
Mexico

Tel: 52-73-194381
Tel: 52-73-194000 ext. 543
Fax: 52-73-194381
Email: areguin@tlaloc.imta.mx

NETHERLANDS ANTILLES

Mr. Patricio D Oleana
Department of Public Works (DOW)
Subdivision Sanitary Engineering
Head Mechanical and Electrical Engineering
Punta Mateo K3 Jankock
Curacao
Netherlands Antilles

Tel: (599-9) 868-6866
Fax: (599-9) 868-6866
Email: curzuiv@cura.net

Mr. Arthur Rodriguez
Depart. of Public Works (DOW)
Subdivision Sanitary Engineering
Head Process Engineering
Landhuis Parera
PO 3227
Curacao, N.A.

Tel/Fax: (599-9) 868 6866
Tel: (599-9) 433-4444 (Head Office)
Fax: (599-9) 461-7969 (Head Office)
Email: curzuiv@cura.net

ST KITTS AND NEVIS

Mr. Errol Rawlins
Deputy Chief Environmental Health Officer
Ministry of Health
Environmental Health Department
Church Street
Basseterre
St Kitts

Tel: (869) 465-2521 ext. 1271
Fax: (869) 465-1316

ST LUCIA

Mr. Errol Frederick
Sewerage Operations Manager
Water and Sewerage Authority
Lanse Road
Castries
St Lucia

Tel: 758-452-5344 ext. 102
Fax: 758-452-6844

ST VINCENT & THE GRENADINES

Mr. Brian George
Engineer
Central Water and Sewerage Authority
New Montrose
PO Box 363
Kingston
St Vincent & the Grenadines

Tel: 784-4562946 ext. 212
Fax: 784-4562552
Email: cwsa@caribsurf.com

TRINIDAD AND TOBAGO

Mr. Khansham Kanhai
Technical Advisor
Ministry of Public Utilities
Government of Trinidad & Tobago
16-18 Sackville Street
Port-of-Spain
Trinidad

Tel: (868) 624-9068
Fax: (868) 625-7003
Email: kkanhai@tstt.net.tt
Email: kappa@cariblink.net

UNITED STATES OF AMERICA

Mr. Louis Salguero
United States Environmental Protection Agency
(U.S. EPA)
980 College Station Road
Athens
Georgia 30605

Tel: (706) 355-8732
Fax: (706) 355-8744
Email: salguero.louis@email.epa.gov

VENEZUELA

Ing. Fanny Rodriquez
Jefe, Division de Calidad Ambiental
Ministerio del Ambiente
Av. Carlos Sanda c/c Delicias
Edif. Capri Apto. 501
Valencia, Venezuela

Tel: 5841-315748
Fax: 5841-674376
Email: Lansdell@telcel.net.ve

APPENDIX 4

LIST OF OTHER PARTICIPANTS

ANGUILLA

Mr. Stephenson Roger
Principal Environmental Health Officer
Primary Health Care Department
Ministry of Health
The Valley
Anguilla

Tel: 264-497-2631/3763
Fax: 264-467-5486

ANTIGUA AND BARBUDA

Mr. David Matthery
Senior Public Health Inspector
Central Board of Health
C/- Ministry of health
All Saits Road, St John's
Antigua & Barbuda

Tel: (268) 462-2936/1891
Fax: (268) 460-5992

CANADA

Mr. Jean-Pierre Dube
Option Environment
2360 Ave. Lasalle, bwuau 202
Montreal (Quebec) HIV 241
Canada

Tel: (514) 257-6380
Fax: (514) 257-6382
Email: jpdube@opt.env.qc.ca

COMMISSION OF THE EUROPEAN UNION

Mr. Peter Collins
Water Expert
European Commission
EC Delegation
8 Oliver Road
PO Box 463
Kingston 8
Jamaica

Tel: (876) 924-6333
Fax: (876) 924-6339
Email: eudeljam@wtjam.net

FRANCE (GUADELOUPE)

Mr. Eric Muller
Direction Regionale de l'Environement de Guadeloup
Alle des Louriers, Circunvallation
PO Box 105
97100 Basse-Terre
Guadeloupe

Tel: (590) 99 35 60
Fax: (590) 99 35 65
Email: diren971@outremer.com

JAMAICA

Mr. Howard Batson
U.S. AID
2 Haining Road
Kingston 5
Jamaica

Tel: (876) 926-3781
Fax: (876) 929-9944

Mr. Bruce Excell
Waste Technology
1 Riverbay Road
Montego Bay
Jamaica

Tel: (876) 979-5756
Fax: (876) 940-4265

Ms Stephanie M Fletcher
Ministry of Health
St Mary Health Department
Port Maria P.O.
St Mary

Tel: (876) 994-2358
Fax: (876) 994-2643

Ms Grace Foster-Reid
Alcan Jamaica Company
Kirkvine PO
Manchester
Jamaica

Tel: (876) 961-7144
Fax: (876) 961-7822
Email: grace@cwjamaica.com
Email: grace-foster-reid@alcan.com

Ms Ining Hsu
St Mary health Dept/U.S. Peace Corps
1A Holborn Road
Kingston 10
Jamaica

Tel: (876) 929-0495 (Peace Corps)
Tel: (876) 994-2358 (Office)
Fax: (876) 994-2643 (Office)

Mr. Maurice Jones
Fluid Systems Engineering Ltd
27 Harbour Street
Kingston
Jamaica

Tel: (876) 922-6670
Fax: (876) 922-7512
Email: mojoe@cwjamaica

Mr. Matthew Krachon
St Thomas Health Dept/U.S. Peace Corps
1A Holborn Road
Kingston 10
Jamaica

Tel: (876) 982-1619

Mr. Desmond Malcolm
National Water Commission
4 Marescaux Road
Kingston 5
Jamaica

Tel: (876) 906-9020
Fax: (876) 906-9019

Mr. Donald D McDowell
Ministry of Environment and Housing
2 Hagley Park Road
Kingston
Jamaica

Tel: (876) 926-1590-9 ext. 2126
Fax: (876) 926-8535

Mr. Rinav Mehta
Environmental Control Division – MOH & U.S. Peace Corps
1A Holborn Road
Kingston 10
Jamaica

Tel: (876) 967-1100-7 ext. 2220
Fax: (876) 967-1280
Email: reendog@kasnet.com

Mr. Malden Miller
Montego Bay Marine Park Trust
Pier 1, Howard Cooke Blvd.
Montego Bay PO #1
St James
Jamaica

Tel: (876) 952-5619
Fax: (876) 940-0659
Email: mbmp@n5.com.jm

Mr. Errol Mortley
Urban Development Corporation
17 Ocean Boulevard
Kingston Mall
Kingston
Jamaica

Tel: (876) 922-8310-4 ext. 2937
Fax: (876) 929-9944
Email: hsaddler@usaid.gov

Mr. Cliff Reynolds
Negril Chamber of Commerce
Box 31 Negril P.O.
Westmoreland
Jamaica W.I.

Tel: (876) 957-4067
Fax: (876) 957-4591
Email: negrilchamber@cw.jamaica.com

Mr. Herrol Sadler
U.S. AID
2 Haining Road
Kingston 5

Tel: (876) 926-3645-9
Fax: (876) 929-9944
Email: hsaddler@usaid.gov

Mr. Gangolf Schmidt
GTZ
C/- SRC
PO Box 350
Kingston 6
Jamaica

Tel: (876) 919-4117/927-1771
Fax: (876) 977-2194
Email: srcgtz@cwjamaica.com

Mr. David Steen
U.S. Peace Corps
1A Holburn Road
Kingston 10
Jamaica

Tel: (876) 978-4061
Fax: (876) 978-4062
Email: crdc@jol.com.jm

Ms Heather Storrud
Ministry of Health/ECD and U.S. Peace Corps
1A Holborn Road
Kingston 10
Jamaica

Tel: (876) 967-1100 ext. 2229
Email: ecd@epi.org.jm

Roger Surtees
International Consultant
Thames Water Int. Consultancy
NWC Bogue Ind. Estate
Montego Bay
Jamaica

Tel: (876) 952-1640
Fax: (876) 971-6204

Mr. Winston Thomas
Pan American Health Organization (PAHO)
Oceana Building
2-4 King Street
Kingston
Jamaica

Tel: (876) 967-4626/4691
Fax: (876) 967-4187
Email: wthomas@jam.paho.org

Mr. Brad Walker
U.S. Peace Corps
1A Holburn Road
Kingston 10
Jamaica

Tel: (876) 906-4186
Email: bawalker@ns.com.jm

Mr. Dean S Williamson
National Water Commission
PO Box 474
Bodue Industrial Estate
Montego Bay
St James
Jamaica

Tel: (876) 952-1640/952-8344
Fax: (876) 979-6090
Email:dwllnson@nwc.com.jm

Appendice 5
Institutional Profiles

THE CARIBBEAN ENVIRONMENT PROGRAMME

Established by the nations and territories of the Wider Caribbean Region in 1981, the Caribbean Environment Programme (CEP) promotes regional cooperation in the protection of the marine and coastal environment. The CEP is an integral part of the Regional Seas Programme of the United Nations Environment Programme (UNEP), and is administrated by its Regional Coordinating Unit (CAR/RCU) in Kingston, Jamaica.

The legal framework for the CEP is provided by the Cartagena Convention that was adopted in 1983. This Convention, the only region-wide environment treaty, is a framework agreement setting out the political and legal foundations for environmental actions to be developed. These actions are directed by a series of operational Protocols, addressing oil spills, protected areas and wildlife (SPAW Protocol), and land-based activities and sources of marine pollution (LBSMP).

The CEP helps to protect the marine and coastal environments of the Wider Caribbean Region through its catalytic and facilitating role. This is accomplished through programmes that strengthen national and subregional institutions, stimulate technical co-operation among countries and by the creation of networks of information and people. The various programmes and activities of the UNEP-CAR/RCU assist the nations of the Wider Caribbean Region to chart a course for sustainable development and environmentally sound practices. The CEP assists in the co-ordination of International Year of the Ocean and has established co-operation with global agreements such as the Convention on Biological Diversity.

The Programme co-ordinates the collection, production, reviews and dissemination of studies, publications and the results of work performed under its aegis. From technical reports, to newsletter, to educational and awareness-raising materials, to technical protocols and agreements, the CEP organizes and hosts many seminars and workshops. These events bring together non-governmental organisations, environmental specialists, scientists, policy makers and others, including representatives of CEP member governments.

The activities of the CEP have been developed to support the implementation of the Cartagena Convention and its Protocols. In this capacity, the CEP has been co-ordinating activities regarding the conservation and management of endangered species and habitats of regional concern, the establishment and management of the protected areas, and the assessment, management and monitoring of land-based sources of marine pollution. The Programme has developed guidelines for best available technologies and practices for sewage and agricultural waste management, as well as oil spills contingency plans. Systematic assistance is also provided on integrated coastal area management through the promotion and application of regional guidelines. Other major activities are the promotion of best environmental management practices in the vital tourism industry of the Wider Caribbean and the creation of a network of marine protected areas.

The CEP is also assisting with the development of a regional network of marine and coastal information and data through the Internet. Databases on government and regional contracts, experts, and projects are maintained. Additionally, the programme develops geographic databases on relevant subjects, such as marine protected areas and endangered species.

The public is kept informed of the environmental activities in the Wider Caribbean through the publication of the CEP newsletter, CEP news, and its dynamic Internet Web site. The Programme is an important instrument for increasing public awareness, environmental education and capacity building through training and the publication of documents and materials.

The members of the CEP are the countries and territories bordering the Caribbean Sea, the Gulf of Mexico and adjacent portions of the Atlantic Ocean, south of 30° North latitude and within 200 nautical miles of the Atlantic Coast. This area, known as the Wider Caribbean Region, includes all the islands of the Caribbean, the North and Central American countries bordering the Gulf of Mexico and the Caribbean Sea, and the northern South American countries as far east as French Guiana. This region is a complex mix of peoples, languages and societies in one of the most culturally and ecologically diverse areas of the world.

The CEP also works closely with numerous organizations in protecting the Wider Caribbean marine and coastal environments. The Programme is primarily funded by the Governments of the region through the Caribbean Trust Fund. Additionally funds are provided by other governments, donor agencies and UNEP.

As an office of UNEP, the CAR/RCU co-operates with Regional Seas Programme and other UNEP initiatives, as well as many organizations of the UN system. International, regional and local non-governmental organizations, as well as academic and research institutions, participate in the many projects of the CEP and assist with their implementation.

More accessible and comprehensive information is available on the CEP web site, http://www.cep.unep.org/. This site provides further detailed information about CEP activities, office and staff. More importantly, the site also makes available to the world our library of technical reports, our quarterly newsletter, project update pages, environmental databases and directories, and links to other Internet resources.

THE ENVIRONMENTAL TECHNOLOGY CENTRE AT MURDOCH UNVERSITY IN WESTERN AUSTRALIA

The environmental Technology Centre (ETC) at Murdoch University was established in 1992, and officially inaugurated in 1994 during the National Conference on Technology Transfer in Remote Communities. The ETC was established by the Remote Area Developments Group of the Institute for Environmental Sciences at Murdoch. The aim of the ETC is to research, develop and demonstrate environmental technologies, conduct education and training, provide consultancy services to industry, and raise community awareness of environmental technologies. Its facilities are open to local industries wishing to test and monitor products within the university infrastructure.

The ETC occupies a 1.7 hectare site on the Murdoch University campus at which thirty-two environmental technologies have been combined to form an integrated operating demonstration system. The technologies used and researched at the site include climate-sensible buildings, renewable energy systems for power supply and water pumping, aquaculture systems, organic waste management, and permaculture. The integrated approach allows research to be carried out on the important interactions between different technologies, rather than just the effect of a single technology. This gives the ETC a considerable advantage over other research institutions which focus on single technologies in relative isolation. The ETC is able to offer holistic and flexible solutions to human needs.

The ETC’s focus is on small-scale environmental technologies, which are cheap to produce and establish, robust, efficient, and easy to operate and maintain. The aim of this is to maximise the opportunities for user communities to "own" the technology, resulting in greater and more sustained uptake of the technology, higher levels of community awareness and involvement, and ultimately a more successful operation. This approach has been successful in remote areas in Australia, and is highly applicable to communities in developing countries, as well as to urban communities worldwide, particularly when applied in collaboration with industry and government.

The ETC has a strong track record of research collaboration and consultancy work with industry and government organisations. It has also established connections with the international environmental research community through its association with the United Nations Environmental Program. The growth and development of the ETC, and the increased value it can thereby offer to local industry, depend upon consolidating and extending these international links.

The ETC at Murdoch University is affiliated with UNEP-IETC as an international centre for the Asia-Pacific Region.

Remote Area Developments Group (RADG)

The RADG was established in the Institute for Environmental Science at Murdoch University in 1985. Its aims are to investigate the problems of small communities in remote areas of Australia, and to develop appropriate technologies to solve those problems and improve the living conditions for people in those communities. Some keyareas of research and development include appropriate technology for water supply and sanitation, revegetation, bush food and communications. The RADG Advisory Committee consists of industry and community representatives.

The RADG established the ETC in order to provide an appropriate research and teaching location for integrated environmental technologies, and to educate and inform the public about environmental issues facing remote communities in Australia. The ETC's activities have expanded since its establishment to include research into application of environmental technologies to developing countries and urban communities as well as remote areas. The RADG is the specific research group associated with the ETC, but the Centre's staff also develop and work on projects not directly linked to the RADG.

Institute for Environmental Science

The RADG and the ETC are key components of the Murdoch University-based Institute for Environmental Science, which was set up in 1977 to foster links between university research and industry. The Institute is based in the Division of Science at Murdoch University alongside the School of Environmental Science, one of the few schools nationally to focus specifically on teaching and research in environmental science. The aim of the Institute is to draw staff from the School into industry-focussed research. Its expertise in marine environments, land-based studies and air pollution has been used to solve industries' environmental problems, and to provide specialist training for government and industry agencies.

Australian Sustainable Development Centre

The ETC will be part of the proposed new Australian Sustainable Development Centre (ASDC) to be established on the Murdoch University campus. This new initiative will link a range of institutions in Western Australia with complementary interests in sustainable development, including the applications of renewable energy, energy efficiency, water and wastewater systems, ecological health, indoor environments, solid waste recycling, transport, city planning, land care and the social aspects of sustainability. Participants in the ASDC will include:

- Environmental Technology Centre (ETC), through the Remote Area Developments Group (RADG);
- Waste Management;
- Australian Cooperative Research Centre for Renewable Energy (ACRE);
- Institute for Science and Technology Policy (ISTP);
- International Centre for Application of Solar Energy (CASE); and
- Murdoch University Energy Research Institute (MUERI).

By integrating and acting as a shop front for these organisations, the ASDC will provide opportunities for increasing research, teaching/training and consulting, with a focus on the international market and the WA regions, as well as across Australia. It is also seen to be an incubator for further industry co-location opportunities at Murdoch. The ETC will bring considerable value to the ASDC through its link with the UNEP and its established track record in integrated environmental technology research. In turn, it will benefit from the synergy provided by the interaction of a range of institutions engaged in environmental research and development.