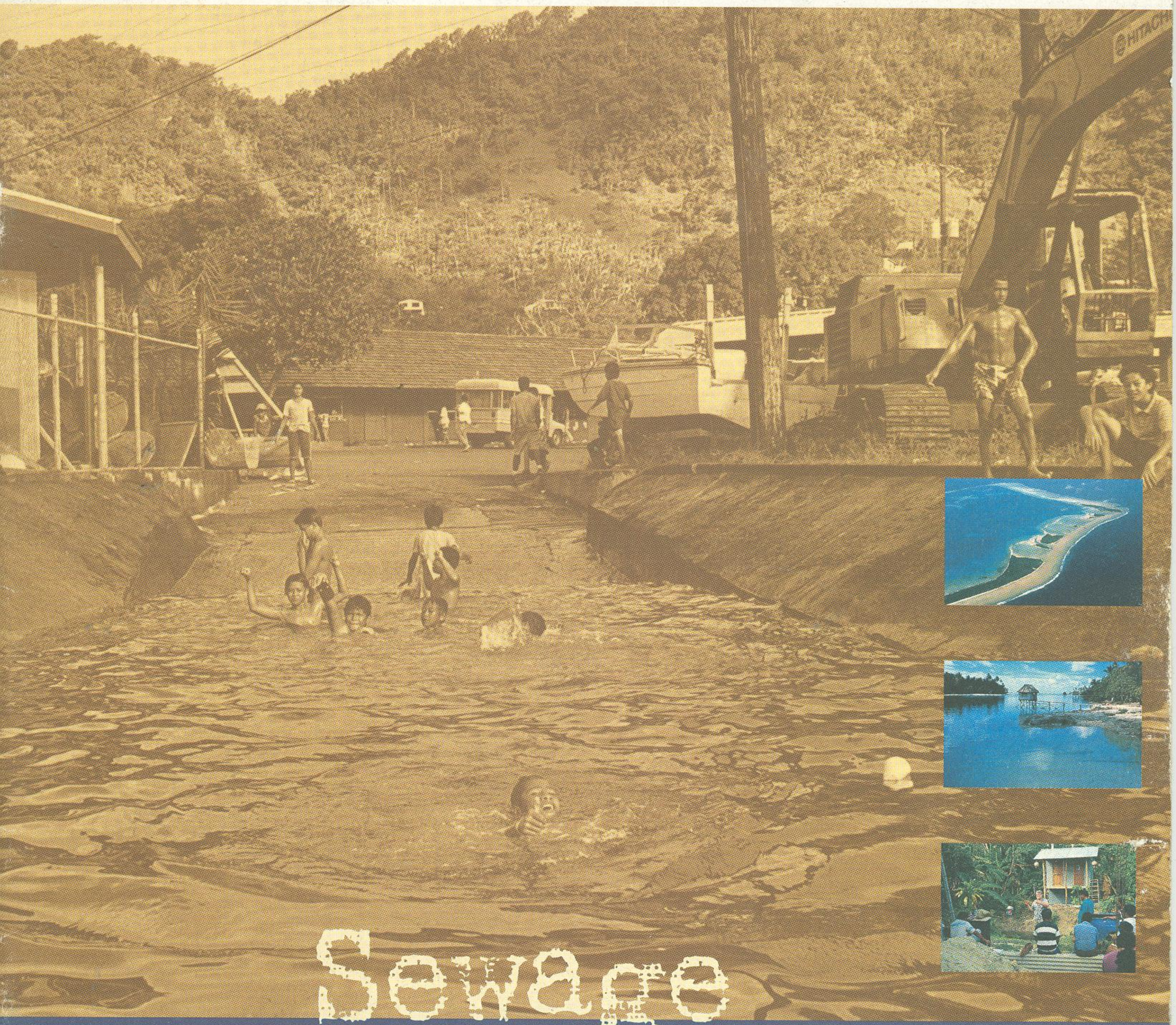
GREENPEACE



Sewage Pollution

in the Pacific

and how to prevent it

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Contents

Executive Summary

Sewage is the most significant source of marine pollution in the Pacific region. Nearly every Pacific island nation has identified critical environmental and public health problems resulting from the disposal of human excrement. These have included algae blooms and eutrophication in lagoons, dying reefs, contaminated drinking water wells and outbreaks of gastro-intestinal disease and cholera. The causes of this pollution include overflowing latrines and privies, water seal toilets, septic systems, sewage treatment plants as well as the complete lack of sanitation facilities in some places.

Globally, sewage is a major component of marine pollution from land-based activities, which account for roughly three-fourths of all pollutants entering the world's oceans. Land-based sources of marine pollution are contributing to an alarming decline in the health of the world's marine ecosystems and their ability to provide for human needs. Sewage along with other forms of pollution from land-based activities is blamed for the decline and collapse of fisheries and tourism, and represents a severe threat to public health in various regions around the world.

These widespread problems are testimony to the failure of the conventional approach to pollution, which attempts to manage and control it by seeking 'proper' disposal options. In the case of human excreta, this has primarily meant using water to carry wastes out of sight – through reticulated sewage systems to centralised treatment facilities, into decentralised septic systems and leach fields, or into the ground directly through simple water sealed toilets. As numerous examples presented in this report clearly show, these conventional sewage treatment options may partially reduce pollution and health problems or shift them from one place to another, but they do not solve them.

Instead, sewage discharges can be prevented entirely by recovering human excreta as a resource rather than disposing of it as a waste. Several innovative treatment options are available which utilise natural processes to convert excrement into useful products and avoid wastewater discharges. These ecologically engineered zero-discharge systems use microorganisms and sometimes plants and animals to convert human excrement into fertiliser, fuel, or valuable plants. Perhaps the simplest and least expensive of these technologies are waterless biological toilets, which utilise soil-based microorganisms to transform excrement into a soil conditioner inside a sealed container. Also known as composting toilets, this technology is in use around the world and many commercially available models are accepted by sanitation officials in Europe and North America. Other examples of alternative sewage treatment technologies include contained wastewater gardens, constructed wetlands and biogas systems.

Recent demonstration projects have shown the viability of waterless biological toilets in Pacific islands. Since 1992, several demonstration units have been successfully operated in Kosrae and Yap in the Federated States of Micronesia through a project started by Greenpeace. Another demonstration conducted by the Centre for Clean Development and the FSM national government in Pohnpei has also been successful. Both commercially manufactured and concrete site-built units were used in these projects. All of the units are functioning properly and users report that they are pleased with the technology.

Recommendations

Greenpeace believes that human excreta is a resource that should be recovered and reused rather than disposed of into the marine environment. Further, using water to transport this material inevitably leads to environmental contamination and is a waste of financial as well as fresh water resources. Greenpeace supports the use of alternative, non-water-carried ecologically engineered treatment systems which use natural processes to convert human excrement into valuable by-products. As a first step in this direction, and where conversion of existing water-based systems is not practical, the discharge of industrial waste to conventional sewage treatment systems should be prohibited, allowing sewage effluent and sludge to be reused for a variety of purposes which pose no danger to public health. In addition, the use of chlorine for disinfection of sewage effluent, which causes the formation of highly toxic chemical pollutants, should be replaced with non-toxic alternatives such as oxygen-based additives or ultraviolet radiation.

Greenpeace recommends that the following criteria guide the selection of technologies for managing human excreta, and serve as the basis of regulatory policy for the prevention of sewage pollution in Pacific Island Developing Countries. Human excreta and domestic wastewater management systems should:

1. Achieve zero-discharge;
2. Recover excreta as a resource;
3. Avoid the use of water;
4. Disinfect without chlorine;
5. Prohibit industrial waste.

In addition, the following measures could significantly reduce the pollution discharged from existing conventional sewage treatment systems:

1. Water conservation;
2. Conversion and beneficial use of sludge;
3. Wastewater reuse;
4. Supplemental treatment using ecologically engineered technologies.

Internationally, Pacific island nations have been instrumental in efforts to protect the marine environment from pollution, including the global ban on ocean dumping achieved through the London Convention. The active participation by island governments in negotiations for a Global Programme of Action for the Protection of the Marine Environment from Land Based Activities, scheduled for adoption in November 1995 at a conference in Washington DC, is important to ensure that the agreement facilitates the implementation of real solutions for sewage and other land-based pollution problems which threaten the well-being of Pacific islanders.

Regionally, the South Pacific Regional Environment Programme (SPREP) must begin to implement programmes designed to assist Pacific island nations to prevent sewage pollution. Key measures which they have proposed but have yet to act upon include:

- training and technical assistance on ecologically engineered zero-discharge sanitation technologies;
- demonstration pilot projects of these technologies;
- establishment of the Pollution Prevention Trust Fund and other mechanisms to fund and finance zero-discharge systems.

Finally, on the national and local levels, agencies responsible for providing sanitation, infrastructure and environmental regulation must move away from failed conventional approaches and toward the alternative solutions outlined in this report. Despite the identification of widespread problems caused by sewage pollution, most local and national governments are not responding with measures that will adequately address them. As exemplified by the programmes of action outlined in many of the National Environmental Management Strategies developed by Pacific island countries in recent years, there is a continued reliance on inappropriate sewage disposal options, rather than prevention-based alternatives.

Since most island nations are dependent on technical assistance from industrialised countries, Pacific island officials must insist that the assistance provided enables them to leap-frog beyond the mistakes which have already been made elsewhere, rather than be condemned to repeat them. As this report shows, the solutions exist. The only real question is, will they be used?

INTRODUCTION

Global Crisis In The Seas

In a region of small islands occupying 30 million square kilometres of ocean, it is easy to see that the well-being of its people is directly tied to the health of the marine environment. The natural resources provided by coastal habitats and the open ocean are the basis for traditional subsistence as well as growing commercial activity. With the exception of highland regions of Papua New Guinea and elsewhere, the cultures and identity of Pacific island peoples are intimately linked with the ocean.

But in a very real way, we are all dependent on the marine environment even in places where this relationship is not as direct. Life on Earth is believed to have sprung from the deep ocean about 4 billion years ago, and it was the development of early photosynthetic marine organisms that created conditions under which life as we know it could evolve by releasing oxygen into the atmosphere. Today the oceans continue to play a major role in global climate regulation, moderating temperatures by absorbing heat in tropical areas and releasing it in temperate zones through the action of currents. The biological activity of the oceans also slows the atmospheric build-up of carbon dioxide, the primary greenhouse gas, and may be helping to delay global warming. Through a process known as 'the biological pump,' marine microorganisms remove carbon dioxide from the atmosphere for use in photosynthesis, with 10% ending up in the deep ocean for about 1,000 years before it resurfaces. In addition to the biological pump, these microorganisms are at the base of the food web that supplies 80 million tons of seafood harvested a year.[1]

Many people in the Pacific rely on the ocean for their livelihoods.

However, increasing population and a wide variety of human activities have caused a global crisis in the oceans. Pollution, habitat destruction, and depletion of marine life worldwide are sapping the ability of the marine environment to sustain human needs. While direct destruction of habitat and overfishing are fairly easy to see, pollution threats are often harder to recognise and understand. A growing combination of new synthetic toxic chemicals, excess levels of nutrients and other natural pollutants are severely undermining the health of the marine environment. The exact impacts of any of these pollutants alone and in combination are extremely complex and difficult to decipher. There is, however, a growing list of undeniable symptoms including the closure of fisheries, food chain contamination, disease and mass mortalities of marine mammals and other species, the transmission of human disease, coral reef destruction and losses of biological diversity.[2]

Coastal habitats such as estuaries, wetlands, coral reefs, and enclosed bays not only bear the brunt of pollution from land-based activities, but they are also the most vulnerable and valuable portion of the marine environment, with the greatest abundance and diversity of marine life. Coastal waters provide the bulk of the world's fish catch and act as nurseries for most pelagic fish. They support most of the subsistence fishing activity in the Pacific islands, and a growing amount of commercial tourism activity also. Worldwide, coastal tourism accounts for half of the multi-billion dollar global tourism industry.

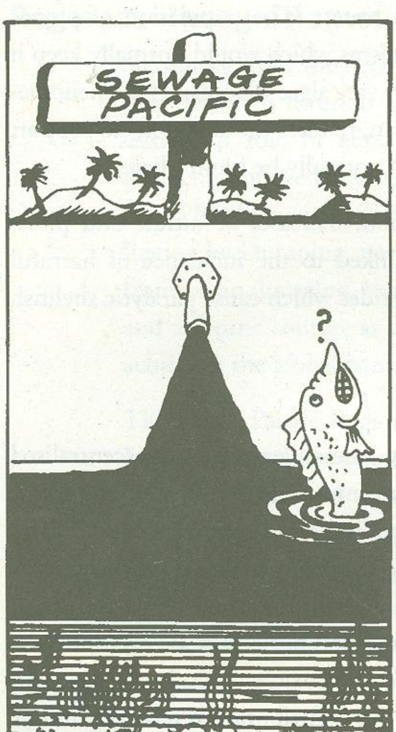
Even in the Pacific, where traditional cultures have lived in balance with their environment for thousands of years, the marine environment faces growing threats from pollution as countries of the region strive to achieve aspirations for economic development. The general dilemma facing Pacific island developing countries was well summarised in The Pacific Way, the regional submission prepared for the 1992 United Nations Conference on Environment and Development:

For thousands of years we have lived a relatively sustainable way of life on our island environments at a fairly low level of material well-being – a level which we no longer consider adequate. We are strongly committed to maintaining the harmony which has characterised Pacific island peoples' relationship with their environment; we do not want the pursuit of material benefits to undermine our cultural systems and values nor to cause any permanent harm to the land and marine resources which have allowed us to sustain life for so many centuries.

This report points in the direction of how this dilemma can be resolved by showing how the largest source of marine pollution in the region can be prevented.

Land Based Sources of Marine Pollution

In recent decades direct ocean dumping and pollution from ships has come under increasingly strict international regulation under the London Convention and the Convention for the Prevention of Pollution from Ships, known as MARPOL. Within the South Pacific, the SPREP Treaty and its protocols offer protection from these sources within the exclusive economic zones of Pacific nations. Currently however, there is no binding international or regional regulation of marine pollution which originates from land-based activities, although this is widely acknowledged to be the largest category of marine pollution.



CARTOON – M MAETARAU

The 1985 Montreal Guidelines, adopted by the United Nations Environmental Program's Ad Hoc Working Group of Experts on the Protection of the Marine Environment from Land-Based Sources, define land-based sources of marine pollution as:

Municipal, industrial or agricultural sources, both fixed and mobile, on land, discharges from which reach the marine environment, in particular: (1) from the coast, including from outfalls discharging directly into the marine environment and through run-off; (2) through rivers, canals or other watercourses, including underground watercourses; and (3) via the atmosphere.

The Montreal Guidelines, which offer a framework for addressing land-based sources of pollution, are a step in the right direction, but they are only voluntary. Over the last few years, a preparatory process has been underway for the drafting of a Global Program of Action for the Protection of the Marine Environment for Land Based Activities based on the Montreal Guidelines and scheduled to be adopted in Washington DC in November 1995.

The Impacts of Sewage on the Marine Environment

About three quarters of all marine pollution comes from human activities on land. Of this, about 44 percent consists of runoff and discharges from land, which includes nutrients, sediments, pathogens, toxic chemicals and thermal pollution. About half of the nutrients flowing into the oceans – which have doubled since prehistoric times – is the result of raw or partially treated sewage discharged directly into coastal waters or carried there indirectly via rivers and streams and through seepage from septic systems and other failing or inadequate land-based treatment methods.[3] In the Pacific, sewage is regarded as the single most significant source of marine pollution across the region.

Nutrients

The flow of nutrients carried by sewage and other sources has severe impacts on the marine environment, particularly coastal areas. In a marine ecosystem, microscopic organisms provide food for aquatic plants as they decompose dead organic matter and consume oxygen in the process. The plants in turn provide oxygen back into the ecosystem through photosynthesis as they grow. The introduction of excess levels of nitrogen, phosphorus and other nutrients from sewage throws off this balance by causing a rise in the population of oxygen-consuming microorganisms, increasing the biological oxygen demand, or BOD. The increased BOD depletes oxygen faster than it can be replenished by the aquatic plants, resulting in a severely depleted level of oxygen, suffocating many animals which need oxygen in order to survive. The decay of these organisms in turn leads to even greater demand for oxygen and thus feeds a vicious cycle of spiralling BOD and anoxic waters. The population of phytoplankton surges as the organisms which would normally keep it in check die off, resulting in vast algae blooms. This phenomenon, known as eutrophication, renders the area unfit to support the marine life which would normally be found there.


Three quarters of all marine pollution comes from human activities on land.

In addition to eutrophication, increases of nitrate and phosphate loadings have been linked to the incidence of harmful algal blooms such as the red tides which cause paralytic shellfish poisoning or ciguatera.[4]

Industrial and Household Toxic Waste

Apart from the nutrients and pathogens contributed by human excreta, most centralised sewage systems in industrialised areas also receive significant inputs of toxic wastes. For example, in the US during the 1980s, some 130,000 industries discharged over 10.2 billion litres (2.7 billion gallons) of wastewater-containing hazardous chemicals a day to the country's publicly owned sewage treatment plants.[5] These figures are thought to be lower than the actual numbers of industries and amounts of waste because many small businesses are exempt from reporting. In addition to these industrial tie-ins, there are also toxic chemicals contained in household products which end up in the sewers, although this contribution is relatively minor in comparison. The US Environmental Protection Agency estimates that the contribution of heavy metals to sewer systems from households is about 19% of the total and only 7.5% for a list of 'priority' organic pollutants.[6]

It is important to understand that sewage treatment plants are not designed to detoxify chemical wastes. Primary treatment units simply filter out floating and suspended material; secondary treatment facilitates the biological degradation of faeces and urine and other similar material to minimise the discharge of putrefying matter to the receiving water; and disinfection destroys infectious organisms, but none of these processes provides much meaningful treatment for toxic chemicals. Most of the industrial and household toxic wastes released into sewer systems are either discharged with the effluent into receiving waters, separated into the sludge which then enters the environment when this material is disposed of, or are emitted into the air. Interestingly, it turns out that a significant portion of these wastes volatise and go into the air, making sewage treatment plants major sources of air pollution.[7]

Toxic By-products from the Use of Disinfection Chemicals

Another important, but relatively unstudied, environmental impact from sewage disposal is the formation of highly toxic and persistent chemical pollutants resulting from the addition of chlorine, chlorine dioxide and other chlorinated disinfection agents. The chlorine from these agents combines with organic compounds in the water (from the sewage as well as natural sources such as decomposing plant material) to form an array of by-products including trihalomethanes, ketones, and dibenzofurans, close relatives of the dioxin family. Many of these chemicals are persistent and bioaccumulate in the food chain, and have been linked with developmental and reproductive impacts as well as cancer in humans and wildlife.[8]

Regional Recognition of the Need To Protect the Marine Environment

Stemming from the deep-seated cultural bonds of Pacific islanders to the ocean and recognition that their future is irrevocably tied to its continued health, the region has long played a leadership role in efforts to protect the marine environment. The Convention for the Protection of the Natural Resources and Environment of the South Pacific Region, known as the SPREP Convention, with its Protocol for the Prevention of Pollution of the South Pacific Region by Dumping, not only calls for the prevention of pollution of the marine environment from ocean dumping, but also from land-based sources, vessels, sub-sea-bed activities, erosion, and airborne sources as well. Pacific Island Developing Countries were also instrumental in achieving the global ban on waste dumping at sea through the London Convention.

The South Pacific Regional Environment Programme (SPREP) 1991-1995 Action Plan for Managing the Environment of the South Pacific Region lists as one of its major objectives to 'reduce, through prevention and management, atmospheric, land-based, marine and freshwater pollution in the region,' and maintains a number of programmes related to that end. Other evidence of strong regional concern for the marine environment include the concerns raised about Japanese plutonium and waste shipments in recent years, and the Waigani Treaty on the importation of toxic wastes currently being drafted under the auspices of the South Pacific Forum.

However, as this report documents, recognition of the need to protect the marine environment has not yet translated into a commitment for action to halt the region's largest land-based source of marine pollution.

SEWAGE POLLUTION PROBLEMS AROUND THE WORLD

The World Health Organisation estimates that 1.7 billion people lacked adequate sanitation world-wide in 1988,[9] and the UN estimated in 1990 that population increases alone would add almost 900 million people to this number by the end of the century.[10] Excreta from most of this segment of the world's population eventually reaches the marine environment via rivers, streams, canals, gullies, direct discharge, and percolation through soils with groundwater.

According to the World Resources Institute, 95% of all sewage in the developing world is discharged untreated into surface waters.[11] Many urban centres in developing countries do not have any sewage treatment system at all, and of those that do, most serve only a small fraction of the population. For example, only 2% of the population of Bangkok is served by a central sewer system, while most of the population rely on septic systems, cesspools and waterways to dispose of their sewage. In Calcutta, 5.5 million people in bustees and refugee settlements have no systematic means of dealing with human excreta.[12]

But this only begins to describe the scale of the sewage pollution problems since the vast majority of sewage treatment technologies which may be considered as 'adequate' still contribute significant amounts of pollution to the marine environment. For example, even though 96% of all households in England are connected to sewers, Greenpeace found in 1986 that oxygen levels in the Thames River had decreased to such an extent that authorities were forced to pump oxygen into the river to prevent massive fish die-offs.[13] Another illustration is a 2.4 million acre 'dead zone' at the mouth of the Mississippi River in the US, created in part by sewage discharges from at least 621 municipal treatment facilities along the river. Nationwide in the US, there are over 15,000 publicly owned sewage treatment plants discharging treated wastewater at a rate of 26 billion gallons per day, most of which eventually makes its way to the sea.[14] As detailed further below, conventional decentralised sewage treatment technologies, including latrines, water sealed toilets and septic systems, which may be considered as adequate from a public health point of view, also contribute significant amounts of pollution to the earth's marine environment.

Globally, the impact of all this sewage polluting the marine environment is being seen through a variety of disturbing symptoms, including an almost worldwide decline and collapse of fisheries. While a combination of factors, most notably overfishing, are to blame, sewage pollution is undoubtedly a significant contributor.

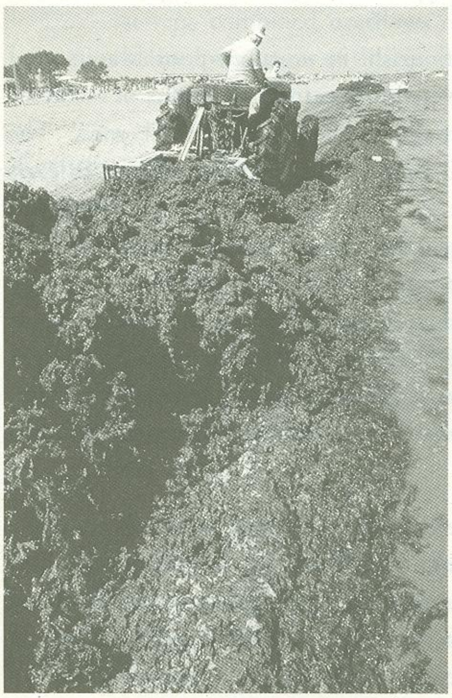
Mangrove areas – a rich source of food – in the Pacific are threatened by pollution from the land.

According to the WHO:

Worsening water pollution in India threatens the livelihood of millions [of people] who rely on fishing. There have also been reports of heavy falls in the fish catch as a result of water pollution in Malaysia, in Lake Maryut in Alexandria, in the Bay of Dakar, around the Indus Delta near Karachi, and in many rivers in China.[15]

Anoxic and low oxygen conditions caused by increased nutrient loadings, that render large areas unable to support most marine life, have been well documented in waters off of the US east coast, the Gulf of Mexico, and the Mediterranean Sea. The phenomenon has been particularly devastating to the fisheries of the Black Sea, where as much as 15,000 square kilometres, or a quarter of its total area, is severely depleted of oxygen each year. This has resulted in major changes in the fish population and a decline in the number of commercially harvested species from 23 to five.[16] The Black Sea's total fish catch plummeted from 900,000 metric tons per year to only 100,000 between 1986 and 1992. More than 150,000 fishing jobs have already been lost, and direct economic losses to the fishing industry have mounted to over US$200 million. Meanwhile, the tourism industry has lost US$300 million each year because of beach closings, algae-clogged swimming areas and outbreaks of cholera.[17]

Red tides and other harmful algae brought on by eutrophication also contribute to the loss of fisheries. The link between the incidence of red tides and increased nutrients found in sewage has been well studied in Japan's Seto Inland Sea. From 1965 to 1976 the number of red tides went up from 44 to 326 per year, parallelling an increase in nitrogen and phosphate loadings. After new regulations reduced the nutrient loadings, the number of red tides began to decrease with 100 reported in 1992. In Tolo Harbour, Hong Kong an 8-fold increase in red tides between 1976 and 1986 was accompanied by a 2.5-fold increase in nutrient loadings.[18]



Excess nutrients from sewage can result in algal blooms such as this off the coast of Italy. These are becoming more common and contribute to the loss of fisheries.

In recent years, red tides have become a growing concern in Australia where the city of Sydney discharges an estimated 1,150 million litres each day of primary treated sewage from deep ocean outfalls at North Head, Bondi and Malabar. It has been asserted that a successional pattern of marine animal deaths along Australia's coast south of Sydney each year over the past decade can be traced to the movement of red tides spawned by the sewage discharges. According to scientist Chris Illert, red tides are formed each summer as the effluent from Sydney's ocean outfalls mixes with the warm waters of the East Australia Current. This is followed by the death of sea birds, whales, and penguins from Sydney all the way to Philip Island near Melbourne as the tides move south around Australia's coast in December and January.[19]

Each year Port Philip Bay in Victoria, Australia is also plagued by toxic algae blooms. For example, the Victorian Health Department found that shellfish from the bay had 125 times the acceptable levels of toxins in January 1992, and eight times above safe levels the following year.[20]

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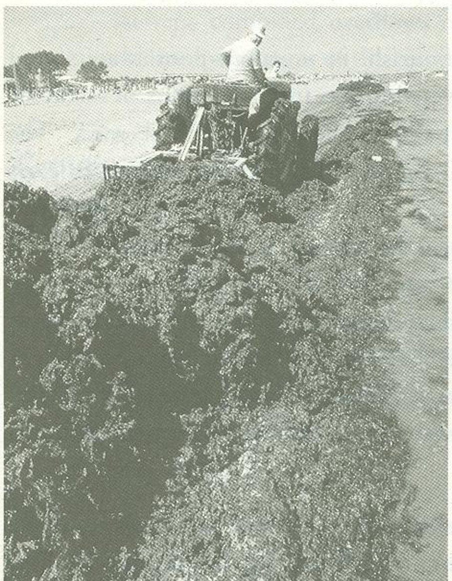

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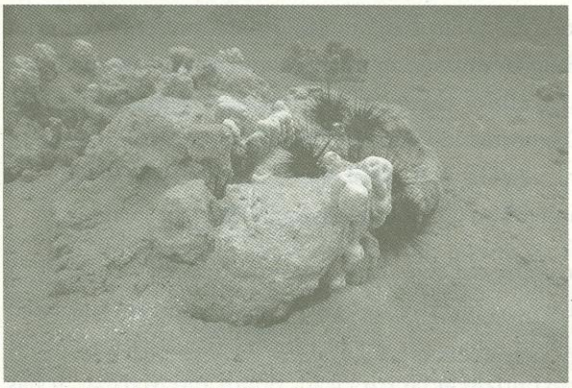
Because of their location in shallow and enclosed areas, shellfish fisheries are extremely vulnerable to the impacts of sewage discharges. For example, Chesapeake Bay in the Eastern US had historically been one of the most productive oyster fisheries in the world, with an annual catch of 20,000 tons in the 1950s. Along with other factors, increased nutrient pollution of the bay contributed to the decline of the oyster catch to under 3,000 tons in the late 1980s.[21] The waters of Puget Sound in Washington State along the Pacific coast, the current US leader in oyster production, are now threatened from increasing water pollution. In 1992, forty percent of Puget Sound's commercial shellfish area and 57 out of 146 recreational beds were closed or restricted due primarily to failing septic systems, animal waste, stormwater runoff and boat waste.[22]

For coral reefs, endangered around the world by many threats, sewage pollution has become a global problem. Degradation due to pollution from sewage as a result of increased population and urbanisation, along with coastal tourism development, has been reported in virtually all regions that support coral reefs. Examples include Kingston Harbour in Jamaica, where by the early 1970s eutrophication caused by sewage discharges and other sources of pollution had already damaged reefs,[23] and the Red Sea, where by 1990, over 4,000 rooms in 26 hotels discharged 3 million cubic meters of primary treated sewage per year.[24] Excess nutrients from sewage have also been blamed as one of the primary causes of the decline of Florida's coral reefs, off the southeastern US, the most popular SCUBA diving destination in the world. Over 200 sewage treatment plants, 22,000 septic tanks, 5,000 cesspools, and 139 marinas harbouring 15,000 boats all contribute nitrogen and phosphorus pollution to the reefs. As one local fisher notes, 'Every time somebody flushes a toilet they are contributing to the problem, myself included.'[25]


Damaged coral – Moorea. Degradation from sewage is one of the many threats facing coral reefs today.

Corals flourish in nutrient-poor waters and suffer severe impacts from the influx of nutrients from sewage discharges in several ways. The increased BOD which accompanies high levels of nutrients starves reef creatures of oxygen and encourages the growth of seaweeds which both benefit from the high nutrient levels and can tolerate low amounts of oxygen. The seaweeds and growth of phytoplankton populations, which also benefit from the nutrients, block light from reaching the corals, harming them still further. In addition, large quantities of nitrates are toxic to corals and high concentrations of phosphates can harm coral directly by inhibiting skeletal growth.[26]

One of the most well documented examples of reef damage caused by sewage is Kaneohe Bay on the island of Oahu in Hawaii. Two sewage outfalls which discharged directly into the Bay until the late 1970s caused extreme ecological changes, killing off most of the coral. After the sewage was diverted into the open ocean in 1978, conditions greatly improved and by the mid-1980s, corals had begun to return.[27] A current study on Australia's Great Barrier Reef is showing that reefs can be adversely effected by exposure to low levels of nutrients for unexpectedly short periods of time. An experiment at the One Tree Island Research Station conducted by scientists from several Australian research bodies and others from the US and Europe has found that the growth of giant clams and reef building algae was stunted by exposure to mild nutrient pollution for just one month.[28]

In addition to the environmental impacts, the public health ramifications of sewage pollution are important to note as well. Nearly half of the world's population suffers from water-related diseases which can be transmitted through contact with water contaminated by human excreta.[29] These diseases are the largest killers of children in the developing world, with diarrhoeal diseases killing 4 million children under the age of five each year.[30]

Cholera can be transmitted through contact with contaminated water and consumption of raw or inadequately cooked fish from those waters, and has historically been one of the world's most feared diseases. Long thought to have been controlled through modern sanitation techniques, outbreaks of cholera in Latin America, Africa and Asia in 1991 caused thousands of deaths.[31] The bacteria which causes cholera is carried by plankton and algae in waters receiving discharged sewage, where it can remain, ready to bloom into disease-causing proportions when conditions are right.[32] This suggests that as long as sewage reaches the marine environment, there will be a risk of cholera epidemics.

Other human diseases related to sewage pollution of the marine environment include ciguatera, which effects over 50,000 people a year in Asia.[33] Certain forms of viral hepatitis, which are not removed by primary or secondary sewage treatment, have been shown to give rise to waterborne epidemics with fatality rates of about 40%.[34]

Public health concerns resulting from the discharge of sewage into the oceans are not limited to developing countries. Elevated bacterial levels forced the closure of more than 2,000 bays and beaches in the US in 1991. Sewage treatment plants, sewage overflows from sanitary sewers, combined overflows of stormwater and sewage, and failing septic systems were all blamed as sources of the contamination.[35]

Sewage Pollution in The Pacific Islands Region

Relatively few 'hard' data are available which document the extent and impact of sewage discharges in the Pacific region. Nevertheless, there is agreement by all who study the problem that pollution from the disposal of human sewage is a major problem in all Pacific island countries. The 1991-1995 SPREP action plan stated that 'the disposal of solid and liquid wastes (particularly of human excreta and household garbage in urban areas), which have long plagued the Pacific, emerge now as perhaps the foremost regional environmental problem of the decade.'[36]

More recently, The Land-Based Pollutants Inventory for the South Pacific Region found that 'the discharge of domestic wastes remains the largest contributor, in terms of quantity of contaminants to the marine environment in the Pacific Region.' The study estimated that 21,675 tonnes of BOD, 12,252 tonnes of suspended solids, 10,499 tonnes of nitrogen and 1,250 tonnes of phosphorus enter the South Pacific Ocean each year from domestic wastewater, making it the major source of these pollutants in the region.[37]

A recent report written by a SPREP consultant offers a good summary of sewage and sanitation problems in Pacific islands:

Treatment and disposal of sewage is the most universal problem in the South Pacific region, as identified in the various national environmental assessments in the region. Increasing pollution from sewage is the result of increasing urban growth and inadequate sewage collection, treatment and disposal systems. As all major urban centres in the region are located on the coast, commonly on lagoons with restricted water circulation, sewage effluent is often retained in nearshore areas.

The reliance of Pacific Islanders on coastal food resources has led to outbreaks of diseases such as cholera (Truk, FSM, Tuvalu, Tarawa, Kiribati) and viral hepatitis (Fiji). Nutrients from sewage and the resulting eutrophication causes phytoplankton blooms that may be correlated with the increased incidence of ciguatera (fish poisoning) in the region. Eutrophication is also linked with decreased water clarity and excess growth of bottom-covering algae, both of which are detrimental to the health of productive coral reefs...[38]

One approach was to have small 'houses' out over the water so the tide carried away the waste,

The following examples from Pacific Island countries serve to illustrate sewage pollution problems across the region.

Cook Islands

While there has been no routine monitoring and little scientific assessment of its impacts, sewage pollution is a recognised problem in the Cook Islands. According to the National Environmental Management Strategy for the Cook Islands (NEMS), most individual households on Rarotònga use improperly installed septic tanks. As commercial activity, housing and tourism grow, there is concern over the potential for contamination of fresh water and the lagoons as sewage pollutants are carried laterally through the water table. Algal growth along the Rarotonga foreshore provides evidence of increased levels of nutrients, although this may also be in due part to the extensive use of fertilisers.

Sewage is also discharged from large hotels directly into the ocean after receiving primary treatment. There is concern both about the effectiveness about this level of treatment and the fact that hotel treatment systems are sometimes inoperative. There is also concern on atolls that the use of pour-flush toilets causes pollution of the shallow water table leading to a high incidence of gastro-intestinal disease.[39]

Federated States of Micronesia

In the Federated States of Micronesia (FSM), sewage contamination is a major concern of all urban centres as well as on outer islands, with high levels of coliform bacteria found in surface and coastal waters. The NEMS for the FSM calls the disposal of sewage along with solid wastes 'one of the most troublesome environmental problems...' for the country, and cites increasing marine pollution from sewage in almost all state centres.[40]

Central wastewater treatment plants in Kolonia, Pohnpei and Chuuk State, constructed with funds from the US Environmental Protection agency, have failed due to lack of trained personnel and funding for maintenance. Although designed to provide secondary treatment, they are generally recognised to discharge essentially raw sewage.[41] In addition, septic systems used in some rural areas are said to be of poor design and construction, while pour-flush toilets and latrines – which frequently overflow in heavy rains – are more common. Over-the-water latrines are found in many coastal areas as well.

The SPREP Land-Based Sources of Marine Pollution Inventory describes the FSM's sewage pollution problems in striking terms:

> *The prevalence of water-related diseases and water quality monitoring data indicate that the sewage pollutant loading to the environment is very high. A recent waste quality monitoring study (as part of a workshop) was unable to find a clean, uncontaminated site in the Kolonia, Pohnpei area.*

A number of studies have found sewage pollution to be adversely affecting coral reefs in the FSM, especially when discharged into lagoons with low circulation.[42]

Fiji

According to the SPREP LBS Survey, numerous marine pollution problems are associated with domestic sewage in Fiji. The Raiwaqa sewage treatment plant in Suva is considered inadequate to protect human health, and individual sewage facilities in unsewered urban areas are also sources of contamination. Inadequate and undersized septic tanks, cesspools and latrines are known to overflow and discharge leachate to marine areas either directly or through streams and storm drains. In addition, the geography of the Suva area does not allow adequate percolation and absorption of septic tank effluent. Subsurface pollutant flows from individual sanitation facilities have been found to be major sources of water quality problems in Fiji.[43]

French Polynesia

Although no data are available, the SPREP Land-Based Pollutants Inventory reports that 'domestic waste is probably the largest land-based contributor to marine pollution.'[44] Reef damage due to the discharge of sewage has been reported, along with disturbances due to dredging, coastal alteration and sedimentation.[45] Also, pollution from sewage and the chemicals used in sewage treatment have been found to adversely impact lagoon ecosystems in Bora Bora.[46]

Kiribati

In Kiribati, high population densities and rapid urbanisation have led to groundwater pollution from the percolation of sewage down into the water table as well as contamination of lagoon water, beaches and shellfish with microorganisms from human excrement. This has resulted in public health problems including an outbreak of cholera in Tarawa in 1977 and a continued high mortality rate from diarrhoeal disease. As summarised by the SPREP LBS Survey, '...issues of domestic waste remain an urgent concern in Kiribati.'[47]

The introduction of a saltwater centralised sewer system in Tarawa in 1983 has failed to improve water quality. In fact, recent research indicates that lagoon pollution has worsened since the facility was installed. Also, studies in 1993 and 1994 found that bacterial contamination and nitrate content of fresh water wells were above acceptable levels.[48] The failure of the sewage system has been blamed on lack of maintenance and funding for repairs, too few connections of private residences to the system, and the continued use of the beach for defecation. However, the corrosive nature of saltwater and its inhibiting effect on bacterial degradation are also likely to have contributed to problems with the system.

Aerial shot Tarawa, Kiribati – sometimes the whole country can be classified as a coastal zone.

Marshall Islands

In the Marshall Islands, signs of eutrophication resulting from sewage disposal are evident adjacent to settlements, particularly urban centres. According to a draft Marshall Islands NEMS, 'algal blooms occur along the coastline in Majuro and Ebeye, and are especially apparent on the lagoon side adjacent to households lacking toilet facilities.' Stagnation of lagoon waters, reef degradation and fish kills resulting from the low levels of oxygen have been well documented over the years. Additionally, red tides plague the lagoon waters adjacent to Majuro.

There is significant groundwater pollution in the Marshall Islands as well. The Marshall Island EPA estimates that over 75% of the rural wells tested are contaminated with coliforms and other bacteria. Cholera, typhoid, and various diarrhoeal disorders all occur.

With very little industry present, most of these problems are blamed on domestic sewage, with the greatest contamination problems believed to be from pit latrines, septic tanks and the complete lack of sanitation facilities for 60% of rural households. As is often the case, poor design and inappropriate placement of these individual systems tend to be identified as the cause of contamination problems. However, this ignores the fact that even the best of these systems in the most

Urban development, Ebeye, Marshall Islands – the most severe sewage problems are evident around urban centres.

favourable soil conditions allow significant amounts of nutrients and pathogens into the surrounding environment, and that the soil characteristics and high water table typically found on atolls significantly inhibits treatment. In addition, the lack of proper maintenance, due to a lack of equipment to pump out septic tanks (as of 1992), is likely to have degraded the performance of these systems even further. Solid waste disposal and animal wastes are also significant sources of marine pollution.[49]

Palau

Forty per cent of Palau's population is served by Koror's secondary sewage plant, which is generally thought to provide adequate treatment. However Koror State has recently expressed concern over the possible contamination of Malakal Harbour to the national government, which runs the plant.[50] Some low lying areas served by the system experience periodic backflows of sewage which runs into mangrove areas due to mechanical failures with pumps and electrical power outages.[51] In other low lying areas not covered by the sewer system, septic tanks and latrines are used which also overflow, impacting marine water quality.[52]

Rural areas primarily rely on latrines, causing localised marine contamination in some areas. Though there have been an increasing number of septic systems installed as part of a rural sanitation program funded by the United States, there is anecdotal evidence that they may not be very effective. Many of the septic tank leach fields may not be of adequate size. In addition, a number of the systems are not used at all, as some families prefer instead to use latrines since the actual toilets and enclosures are not provided with the septic tanks as part of the program.[53]

Solomon Islands

Marine pollution from sewage disposal is a growing problem throughout the Solomons. The problem is particularly acute in Honiara, where the domestic wastewater for 75% of the population is discharged raw through 14 outfalls along the shore. In addition, septic tanks and latrines leach through low porosity soils and into rivers, streams and marine waters, and many over-the-water latrines are found in squatter settlements.[54]

Tonga

All domestic wastewater in the country is discharged to individual septic systems and latrines. Although there is little monitoring of coastal waters, these sources are known to have contaminated the groundwater in the Nuku'alofa area so the potential exists for marine pollution resulting from further underground flows of pollutants.[55] Contamination of shallow reef areas from hotel sewage discharges on Tongatapu and Vava'u has been a potentially serious problem, particularly at Nuku'alofa, where one hotel used to discharge up to a million gallons of effluent a month onto a reef flat. Although the sewage system was subsequently changed, the new outfall has reportedly not been monitored.[56]

Vanuatu

Sewage pollution is considered one of the most serious environmental problems in Vanuatu, with a high prevalence of water-related disease. Studies have identified land-based sanitary facilities as the source of microbial and nutrient contamination which is carried into lagoons around Port Vila by rapid groundwater flows. Combined with poor natural flushing, this has resulted in decreased oxygen concentrations, high turbidity and contaminated food sources in these lagoons.[57]

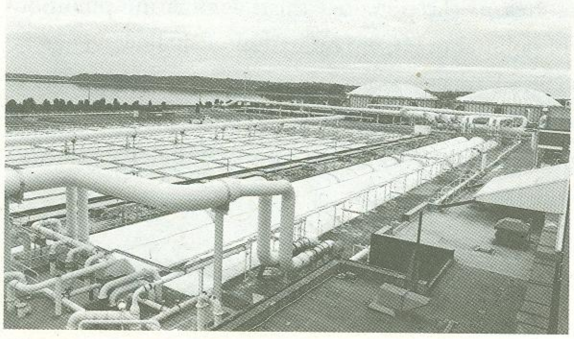
Western Samoa

The greatest amount of sewage is discharged from the Apia area, Western Samoa's largest population centre. There is no public sewage system and the majority of the population is served by individual systems. Although limited data are available, most septic systems are said to be poorly designed and placed. High soil percolation rates in most areas are thought to transport pollutants to nearshore waters. In low lying areas, poor drainage and percolation rates result in ponding of wastewater, much of which makes its way to the marine environment via surface flow.[58]

The Failure of the Conventional Approach

The widespread problems described in this report attest to the failure of the conventional approach to pollution, which attempts to manage and control it by seeking 'proper' disposal options. In the case of human excreta, this has primarily meant using water to carry wastes out of sight - through reticulated sewage systems to centralised treatment facilities, into decentralised septic systems and leach fields, or into the ground directly through simple water-sealed toilets. Typically, these conventional sewage treatment options may partially reduce pollution and health problems or shift them from one place to another, but they do not solve them. Rather, the conventional approach has been guided by an assumption that the pollution which results from these technologies can be safely assimilated by the environment.

In urban areas, excreta management commonly consists of water-flush toilets linked to an underground network of pipes that carries the waterborne excreta to a central wastewater treatment facility. With typical water-flush toilets, some 66-95 litres of water is used to flush away an average adult's daily body products – 200 grams of faeces and one litre of urine. The resulting dilute solution of excreta is diluted even more by the greywater – water used for washing, bathing, etc. – that is also carried by the network of pipes. The now very dilute solution of waste is carried to a central wastewater treatment facility, where it undergoes varying degrees of physical, biological and chemical treatment. In some cases, there is no treatment, simply direct discharge to rivers, lakes or coastal waters.



Mangere sewerage plant, Auckland.

When treatment is provided, the end-products are an aqueous effluent and sewage sludge. This treated effluent – which commonly carries an array of excretal nutrients as well as water-soluble chemical contaminants introduced in household products, industrial discharges or the treatment itself – is discharged into the receiving water. The sewage sludge, which commonly contains nutrients and less soluble chemical contaminants, must be given further treatment such as composting prior to final disposal by burial or land application, although more often than not, it is simply dumped in the most convenient place.

One of the ironies of conventional sewage treatment plants is that the greater the level of treatment, the greater the amount of sludge which is generated. For example, as a result of legislation mandating increased levels of treatment for municipalities in the US, the volume of sludge being dumped at sea increased by about 60% between 1975 and 1985.[59]

A major problem with large centralised systems is that they are subject to frequent failures and rarely work well. In the Pacific, needed parts and expertise may be unavailable for long periods of time. The following description from the Federated States of Micronesia's National Environmental Management Strategy serves to illustrate these problems:

> *There is a central sewer system in Pohnpei which covers almost all of Kolonia and part of Nett. The sewage treatment is non-operational and raw sewage is dumped into a confined recreational bay area; and five of the six lift stations routinely by-pass sewage into local rivers. The sewer system is poorly constructed and pipe leakage contributes to contamination of groundwater and surface water aggravating existing health hazards...maintenance is now virtually non-existent due to severe shortages of resources and funds.*

Not only are conventional centralised sewage systems failing to solve sewage pollution problems, they are prohibitively expensive as well. For example, the US Environmental Protection Agency estimates that the cost of unmet needs for wastewater treatment of US municipalities totalled $108 billion in 1992.[60] It is hard enough to imagine where the money to pay for this expansion of infrastructure will come from in the current political and economic climate in the US, but it is inconceivable that Pacific island developing countries which have little or no infrastructure to start with will ever be able to afford to build and maintain an extensive sanitation system based on conventional technologies.

Conventional decentralised sewage treatment options such as septic systems and water sealed (also called pour-flush) toilets, which have been encouraged as a public health measure, are often a threat to ground and coastal waters. Water sealed toilets essentially place harmful pathogens and nutrients from human wastes directly over the water table. Although in certain soils and under the right conditions some digestion can take place, nitrogen and other pollutants still generally remain in a form which present a health hazard. As noted previously, there is concern about their use in the Cook Islands and elsewhere. In the FSM, Yap's former Lieutenant Governor held up several rural sanitation projects to install water sealed toilets in outer island atolls over the last several years because of worries that they would contaminate groundwater.[61]

The limitations of septic systems are also increasingly being recognised around the world as more and more communities have had their ground and surface waters contaminated with high levels of nitrogen from failed systems. The following examples highlight these problems:

- Studies by government agencies and university scientists in the US coastal state of North Carolina have found that septic systems have contaminated nearby shellfish harvesting waters through both surface and subsurface flow of pollutants, causing vast areas to be closed to harvesting. It is estimated that 90% of septic tanks installed in unsuitable areas will fail to some degree within the first year's use.[62]

- An investigation by the Oregon State Health Department, US, of a 19-county portion of the state found that the average failure rate of septic systems was 52%.[63] In one Oregon county, hazards created by failing systems led to a moratorium on construction in 1977, and a subsequent survey found greater than a 60% failure rate.[64]

- A survey of groundwater for nitrates in an unsewered town in India revealed 59 out of 139 wells had been contaminated with high levels of nitrates, mainly from infiltration of septic tank effluent.[65]

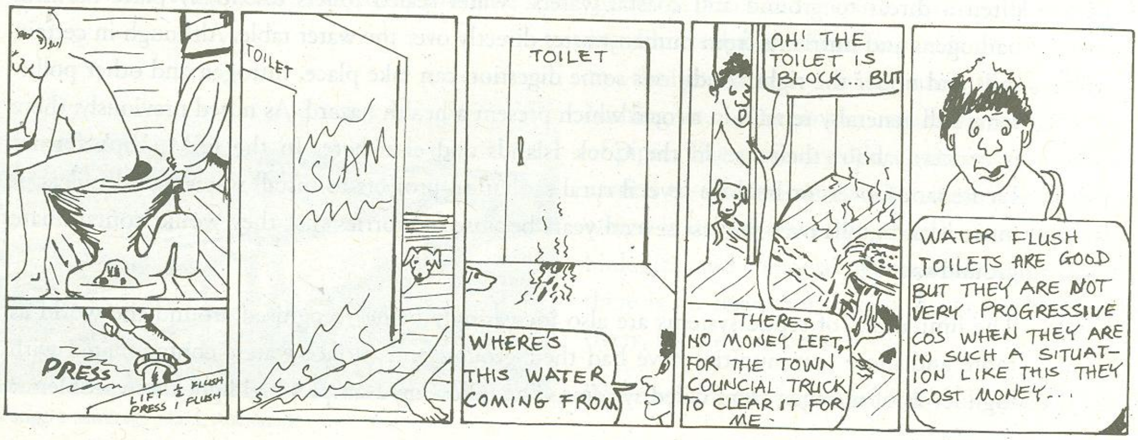
- In Perth, Australia, pollutants from septic systems used by a third of the city's population threaten to contaminate groundwater and pollute the Swan estuary, which is hydrologically connected to surrounding areas.[66]

According to SPREP, groundwater pollution problems were reported by 85% of Pacific countries in 1991. Once the groundwater is polluted, it is prohibitively expensive, if not impossible to clean. In 1993, the suburban city of Pomona in the US state of California spent US$4 million on a small treatment plant (serving the needs of just 10,000 customers) to remove nitrogen from groundwater which had been left there decades ago by septic systems and agricultural practices.[67]

In addition to the threat of contamination, the use of water to flush away human excrement can tax valuable and limited fresh water resources. On low-lying atolls and coastal areas of larger islands, this not only wastes water directly, but can cause salt water incursion of the water table. Salt water is used for flushing in some systems; however, this can inhibit the microbial processes which serve to decompose wastes and kill human pathogens.

Globally, some 80 countries with 40% of the world's population suffer from water shortages at some time during the year. Chronic fresh water shortages are expected by the end of the decade in much of Africa, the Middle East, northern China, parts of India and Mexico, the western United States, northeastern Brazil and the former Soviet Central Asian republics.

In the South Pacific, water shortages were reported by 70% of the region's countries in 1991.



Cartoon – M Maetarau

Many Pacific islanders express hope for desalination to meet their growing fresh water needs; however, it seems unlikely to contribute significantly any time in the near future. About 13 million cubic meters of fresh water were being produced per day in 7500 desalination facilities around the world in 1990, accounting for barely 1/1000th of all fresh water consumption. The cost of water produced through desalination is several times more than water supplied by conventional sources, and it requires much more energy, at present generated almost entirely by the combustion of fossil fuels.[68]

The Need for Precaution and Prevention

It is clear that the conventional approach to the management of human excrement has failed. Rather than blaming sewage pollution problems on 'inadequate disposal,' it must be recognised that all disposal options inevitably lead to pollution.

Only a policy of zero wastewater discharge based on the precautionary principle can guarantee protection for the marine environment as well as public health from sewage pollution. The precautionary principle stipulates that action should be taken to prevent the impacts of an activity, even in the face of scientific uncertainty about those impacts, if the potential impacts are great and the risk sufficiently high. While it will always be difficult to ascertain the impacts of a particular sewage discharge, particularly before those impacts occur, the cumulative evidence of widespread environmental impacts resulting from the use of conventional sewage treatment technologies as illustrated in this report suggests that a policy of zero discharge is warranted.

The precautionary principle implies that we should find out how little damage we can do rather than how much damage the environment can handle. Assumptions that the environment has the capacity to assimilate pollutants in sewage must be replaced by the presumption that human activities should not interfere with natural systems. The conventional approach to pollution based on disposal and control oriented strategies simply can not achieve this. Fortunately, the approach of pollution prevention can.

Sewage pollution can be prevented by recovering human excreta as a resource rather than disposing of it as a waste. In natural systems, there is no waste: all of the products of living things are used as raw materials by others. By flushing our excrement down the toilet and turning it into sewage, we break this cycling of nutrients and create pollution problems. If we instead mimic nature by turning what had been waste into valuable products, there will be no sewage to dispose of. Further, wastewater discharges, contamination from leaky pipes, and the waste of fresh water resources can be prevented by eliminating the use of water as a transport medium for excrement.

Leaders from island nations around the world called for just such changes of approach in 1994 in the Programme of Action for the Sustainable Development of Small Island Developing States resulting from the global conference in Barbados:

> *Given that long-term disposal options are limited and will constrain sustainable development, small island developing states will need to look for ways of minimising and/or converting wastes, such as sewage, into a resource (eg. fertiliser for agriculture).*[69]

While adopting this new approach will require changes in attitudes, it will not require a sacrifice of sanitation or aesthetic standards. As described below, technologies are available which can prevent sewage pollution and still offer the modern convenience of conventional technologies.

Practical Solutions

Ecologically Engineered Zero-Discharge Systems

Several innovative treatment options are available which utilise natural processes to digest human excrement and avoid wastewater discharges. Their common features are that they are contained to ensure that no pollutants are discharged to the surrounding environment and that they use a combination of microorganisms, plants and sometimes animals to consume organic materials and convert them into a form that has value, such as food, fuel or fertiliser.

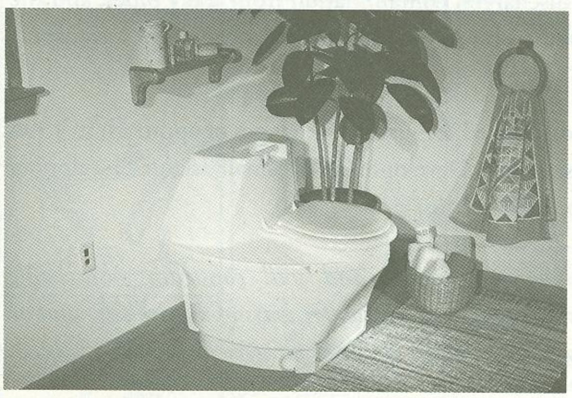
Ecologically engineered treatment technologies are effective, sustainable and inexpensive. Unfortunately, however, there has been a hesitance to use alternative systems, due to a number of factors. Civil engineers and sanitarians often lack knowledge about alternative systems, and since most often their training has been in the conventional approach, they may be reluctant to change. Also, there is a lack of incentive in the private sector to advocate alternative systems because they are usually much less expensive than conventional ones and would therefore reduce the amount of money made by engineering and construction firms. This is ironic, since the overall economic impact of using ecologically engineered treatment technologies is quite positive.

Several of these alternative systems are described below:

Waterless Biological Toilets

Waterless biological toilets, also known as 'composting toilets,' use natural aerobic soil organisms to transform human excrement into a harmless residual called humus, inside an enclosed container. In contrast to most latrines, they are aesthetically pleasant and any odours generated by the process are carried directly out above the roof through a ventilation pipe. Small, attractive commercial units are available which are not much bigger than an ordinary flush toilet and easy to install. Larger units with greater capacity can be purchased and installed into appropriately designed buildings or built on-site from concrete and other locally available materials.

Toilet waste is deposited into a digestion chamber where excess liquids are evaporated and a combination of many different microorganisms decompose the solids, just as would eventually happen to all organic materials if they were left out in the natural environment. Because the conditions in a biological toilet are controlled to promote the process, decomposition occurs relatively quickly and does not produce many of the unpleasant odours normally associated with sewage.


Modern composting toilet

The humus produced by the process is an excellent soil conditioner, free of human pathogens when the toilet is properly maintained and allowed adequate residence time in the digester. To provide an extra measure of safety, the humus can be trenched around ornamental plants or tree crops such as bananas to avoid human exposure or direct contact with food crops.

This technology has been in use around the world including Europe and the United States for two decades. Numerous national agencies and laboratories have developed exacting performance standards for biological toilets. Systems meeting these standards are accepted by government health officials worldwide.

Pollution is prevented and, since water is not used as a transportation medium as is the case with conventional flush technology, potable water resources can be utilised for more pressing human needs such as drinking and cooking. While biological toilets do require some maintenance to assure proper operating conditions, they utilise relatively simple technology which is not subject to the breakdowns and failures of large centralised treatment plants.

Not only are they arguably the most environmentally sound treatment technology for human excrement, but waterless biological toilets may be the most economically sound as well. Because the collection and transport of wastewater usually represents 70-90 percent of a wastewater system's total construction costs,[70] the use of waterless biological toilets – which eliminate this cost altogether – can lead to tremendous savings. They also tend to be much less expensive than waterborne decentralised conventional treatment technologies such as septic systems, which require the digging of a leach field as well as plumbing costs.

When used in combination with ecologically engineered technologies for managing greywater, such as the contained wastewater gardens described below, biological toilets can achieve zero discharge of wastewater from homes, commercial establishments and public facilities. While such combined biological toilet/wastewater garden systems can be easily maintained by individual families, there could also be centralised responsibility for maintenance when used on a village-wide scale. An appropriate agency could be given responsibility to inspect systems and assist homeowners to ensure that the systems function properly. Alternatively, this function could be provided as a service by private enterprise. Because the cost of these systems is so much cheaper than conventional ones, such a maintenance program could be feasible.

Contained Wastewater Gardens

One innovative system for managing the wastewater generated by cooking, bathing and washing (known as greywater) that remains when toilet wastes are eliminated through the use of waterless biological toilets, is the Greywater Garden™ developed by a company in the US called Sustainable Strategies. Wastewater is diverted into contained garden beds which utilise all of the excess water, break down the organic and inorganic compounds and consume the nutrients.

Greywater is filtered and drained into ecologically engineered gardens where aerobic microorganisms transform the constituents of greywater into simple compounds which are used as nutrients by broad leafed vascular plants (banana, canna lily, taro, etc.). The water moves upward to the surface through capillary action and is evaporated by the sun. Evaporation also occurs within the bed as aerobic bacteria release heat as they metabolise the nutrients in the greywater and this heat drives water into vapour which is forced to the surface. Water is also removed through transpiration as it is absorbed by plant roots, drawn up the stems and trunks into the leaves where it is utilised in plant growth and released as water vapour.

The planted beds are shallow, covered trenches filled with crushed stone (gravel) and sand. Perforated pipes are buried in the sand to distribute evenly the filtered greywater and air along the length of the trenches. The trenches are about 45-60 centimetres (18-24 inches) deep to maintain an aerobic environment and maximize the uptake of water and nutrients by plant roots. Air is introduced by venting the distribution pipes to supply oxygen for aerobic bacteria and protozoa. These aerobes will transform the complex molecules of soaps and detergents, as well as food, dust and other particles in greywater into simple compounds that the plants can utilise as food. The leaves and other trimmings from the plants in the garden are harvested and composted along with the residual humus from biological toilets.

In order to insure that the greywater does not seep into the ground or nearby surface water, a watertight liner is used to line the bottom and sides of the garden. To minimise infiltration from rainfall in relatively dry areas, the garden is well crowned and perimeter drainage ditches carry away storm water that might otherwise enter the bed. In wetter areas, the bed can be placed next to a building under a roof overhang, or inside a greenhouse.

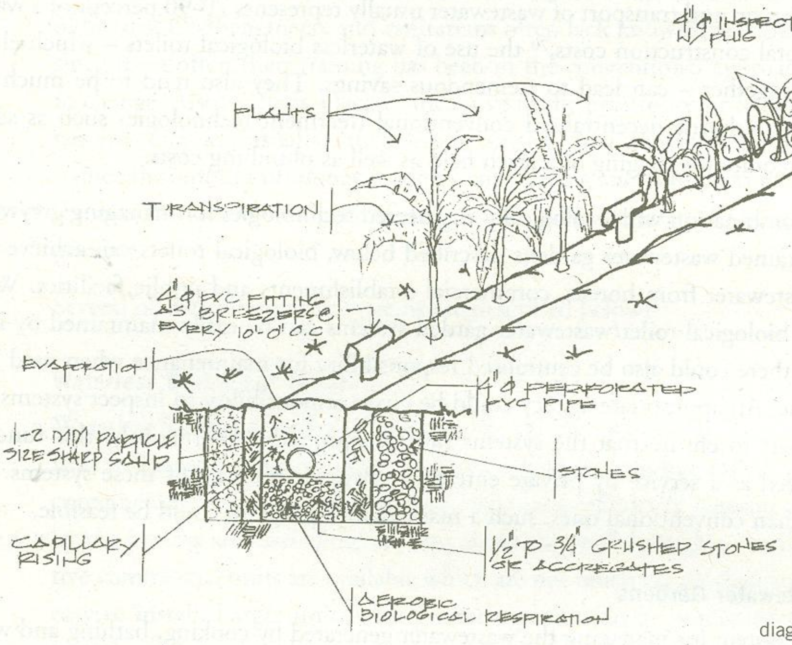
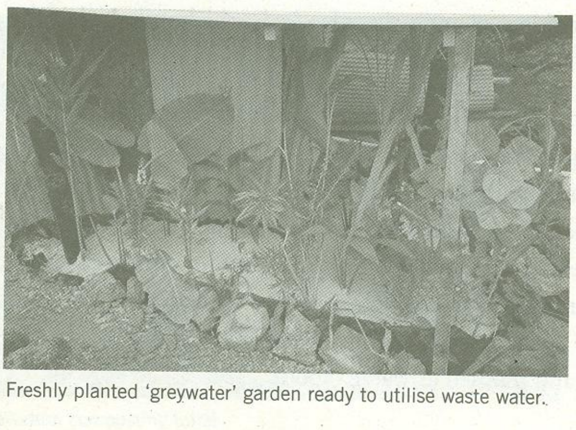


diagram of grey water garden layout

The plant species are selected for their rapid growth and high water requirement and the gardens are sized to contain and consume all of the greywater generated. One appeal of this technology is that the gardens can be used to grow beneficial plants or serve as attractive landscaping when integrated into building site design. An additional benefit of greywater gardens is that they can ensure adequate irrigation, even in times of drought. These systems can replace septic tanks and be used to manage combined wastewater in situations where greywater and human wastes can not easily be separated.

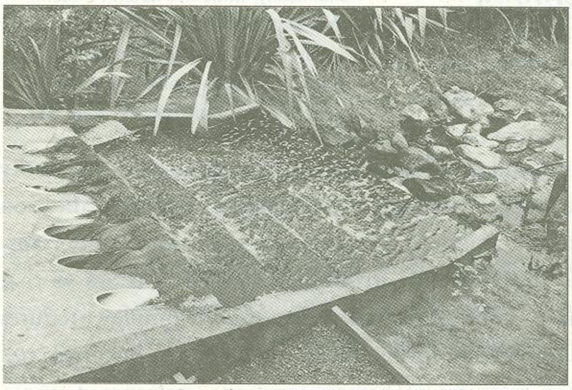


Freshly planted 'greywater' garden ready to utilise waste water.

Constructed Wetlands

While not quite achieving zero-discharge, artificial or 'constructed' wetlands use the ecological engineering approach to attain levels of treatment for combined wastewater generally superior and at less cost than conventional sewage treatment technologies. Variously called rock/plant filters, reed bed treatment systems and other names, these systems use a variety of aquatic plant species to mimic the natural pollutant removal which occurs in wetlands ecosystems.

In recent decades this technology has been advanced by researchers around the world, including scientists at the US National Atmospheric and Space Administration (NASA). Hundreds of these types of systems are in use across North America and Europe, serving small communities as well as individual homes and commercial establishments. They have been used to treat a variety of waste streams including domestic sewage, wastes from food processing, and agricultural wastes. Some, such as those developed by Lemna Corporation in the US, have achieved commercial success and notoriety. These systems, which are works of art as well as sewage treatment plants, use lemna (duckweed) floating on shallow ponds held in place by a grid of baffles which can be shaped into attractive designs.[71]



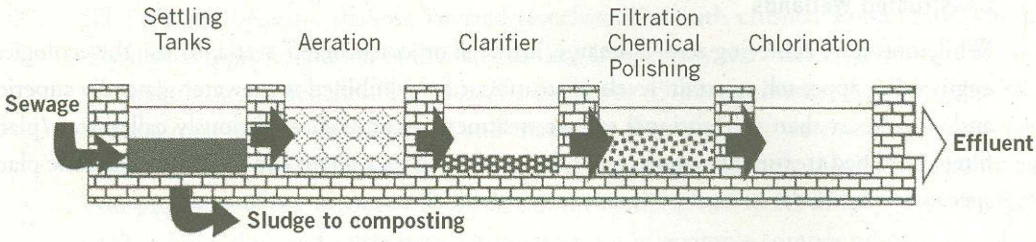
Using wetlands to filter wastewater and remove pollutants

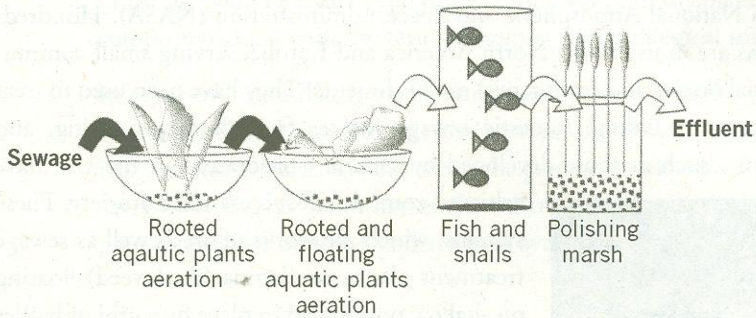
In artificial wetlands systems, wastewater moves either through a bed of soil or gravel in which reeds (phragmites) or other wetlands/marsh plants are growing, or through a shallow pond or trench upon which aquatic plants such as water hyacinth or lemna grow. Treatment is accomplished by a number of biological, physical and chemical processes which take place within the system. Key to this process is the cooperative growth of plants and microorganisms associated with them. The plants in these systems transport oxygen from their leaves down into the root zone, and in other ways create conditions for aerobic bacteria to grow and transform pollutants into fertiliser for the plants. Removal of nutrients and significant reductions of BOD and suspended solids are achieved along with the removal of some heavy metals and organic chemicals.

Because artificial wetlands rely on living systems instead of mechanical action to accomplish sewage treatment, they are typically much less expensive to construct, operate and maintain than conventional treatment plants. They also tend to be fairly hardy and able to withstand a wide range of operating conditions.

Solar Aquatics Systems

A step beyond the more simple artificial wetlands are more complex constructed ecosystems such as Solar Aquatic Systems™ developed by Ecological Engineering Associates in the US. Using a greenhouse to enhance control of the biological activity, wastewater is circulated through a series of clear tanks and marshes, each with its own aquatic ecosystem of bacteria, algae, plants, animals and fish. These enclosed ecologically engineered systems are presently in use in several municipalities in the US including the towns of Harwich and Marion, Massachusetts and the city of Providence, Rhode Island.





Conventional treatment, above, cleans wastewater physically, biologically and chemically, while the natural systems such as the one created by Solar Aquatics, left, rely on the cleansing power of microbes, plants and fish alone (source: *Calypso Log*, June 91).

In this treatment process, sunlight, oxygen, and the living organisms work together to purify the water where contaminants and nutrients are bound up or metabolised. Water purification occurs sequentially, beginning with the introduction of contaminated water into large, translucent tanks of aerated water. The tanks are positioned in rows and piped in series so that gravity creates a stream through each in line. The first tanks largely contain complex mixtures of bacteria. In succeeding tanks, more complex life forms, including algae and invertebrates such as snails, are added to the complex mixtures of bacteria and the oxygenated water. Subsequent tanks downstream contain even more complex life forms; higher plants, other molluscs, and eventually, fish.

In the first tanks, microscopic bacteria break down or consume organic matter and nutrients, which cause their populations to grow. Algae, in turn, thrive on the nutrients released by the growing bacterial populations, and these algae grow and reproduce rapidly because of the abundance of food. Snails consume the algae, and diverse food chains are created, with some organisms breaking down compounds, while others take them up, and still others acting as catalysts for the many processes which comprise the food chain. Further on, plants are rafted on the water, allowing their roots to transport oxygen into the system. In the final tanks, fish, such as tilapia and bass, swim in clean water. Final purification takes place in an artificial wetland or engineered marsh. Ultimately, wastewater is transformed into tertiary quality water.

The plant material grown through the process can be harvested regularly and composted for use on gardens. Research indicates that many harvested plant components will have commercial value as horticultural, medicinal and nutritional products.

In addition to the process system, there are the support facilities including headworks for the up-front wastewater storage and equalisation, a compost facility for sludge and vegetative wastes, operations and mechanical buildings, and an effluent discharge area consisting of a marsh, leaching field or aquaculture ponds.

In tropical settings such as Pacific islands, an ecologically engineered system such as this could be designed using outdoor ponds and employ native plant and animal species.

Biogas Systems

The recovery of biogas, a mixture of methane and carbon dioxide produced by anaerobic bacteria as they digest organic materials, has long been practiced as a part of sewage treatment. Biogas produced from the town septic tank was used to light streets in Exeter, England in the late 1800s and today it is used as a source of energy for operations in sewage treatment plants all over the world. While anaerobic digestion is a standard method of conventional sewage treatment, specialised digestion systems can be designed to maximize the output of biogas, and to recover the solid and liquid residues for use as fertiliser. If all of these out-puts are fully utilised and not allowed to enter the environment as pollutants, then biogas systems can be an environmentally sound method of managing human excreta.

Although these systems are more complex, and require a greater initial outlay to construct than the primarily aerobic systems previously described, the end products have a higher value and can return the investment in a relatively short period of time. Both small-scale, home-built and larger, high-tech anaerobic digestion systems are in use around the world, and many are designed to convert biodegradable solid wastes, agricultural and food-processing wastes as well. Since the mixing of organic components of the solid waste stream such as paper and cardboard and sewage provide a beneficial balance of nutrients for the anaerobic bacteria, these systems offer the opportunity to simultaneously solve several pollution problems at once.

Since the 1950s, many small systems have served individual families in India by producing 'Gobar-gas' from domestic and animal wastes. Human and animal excrement, along with left-over food wastes are fed into the digester which yields gas used for cooking and fertiliser used on crops. Although in the past many biogas producing systems were subject to frequent upsets due to changes in waste inputs and operating conditions, recent advances in the technology have made newer systems much more stable.

Waterless Biological Toilet Demonstration Projects In The Pacific

Several demonstration projects involving waterless biological toilets have been conducted in Pacific islands during the last several years. In addition there are an unknown number of systems in private use. Two recent projects demonstrating the viability of this technology within the region are described below.

Greenpeace Micronesia Waterless Biological Toilet Demonstration Project

Starting in 1992, Greenpeace has conducted a demonstration project to introduce waterless biological toilets in Yap and Kosrae in the Federated States of Micronesia. The project's objectives were to promote the concept of pollution prevention, stimulate interest in zero-discharge technologies and develop the local capacity to build and maintain biological toilets using locally available materials and labour.

Project Description

The project began with workshops providing an overview of sewage problems, the concept of pollution prevention and the principles behind alternative biological treatment technology, focusing on waterless biological toilets. The project design was first to install a commercially available model in an appropriate location, followed by construction of a design which could be made with locally available materials. Local participation was emphasised throughout.

In Yap, the primary local sponsor was the Yap Community Action Program (YapCAP), a non-profit agency which provides a number of community support services including the construction of water catchments and rural sanitation facilities. There was also strong participation from the Yap State Environmental Protection Agency and the Departments of Health and Education. Other participants included the Yap Institute of Natural Science, local business people and interested members of the community. In addition, the Lt. Governor along with other government officials and some of Yap's traditional village chiefs were kept informed of the project's progress.

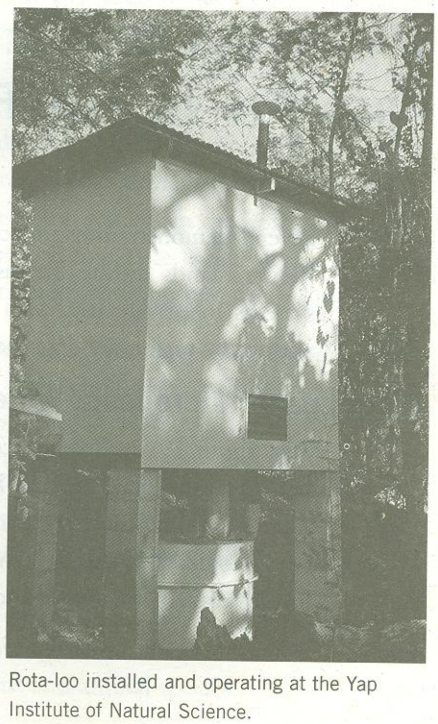
Workshop on composting toilet in FSM with Greenpeace prototype toilet in background.

The lead organisation in Kosrae was KCAP, the Kosrae Community Action Agency. Planning was also carried out in close consultation with several key state government agencies including the Office of Budget and Planning, the Department of Conservation and Development and the Department of Health Services. Participation in the workshops also included representatives from the Department of Education and other agencies as well as representatives from several of Kosrae's villages.

Workshops

In both Yap and Kosrae, two-day workshops were held in March 1992 to introduce the concept of pollution prevention, alternative biological treatment technologies, and to plan further the demonstration project among the group. About 20 people attended each session. Slide presentations, videos, handout materials and group discussions were used to cover the issues of clean development, wastewater problems and conventional solutions, ecological alternatives, and to provide a basic understanding of the construction, operation and maintenance of waterless biological toilets.

In Kosrae, an oversight committee made up of the key 'constituencies' involved with the project (KCAP and the major government agencies) decided that the demonstration would be located at the home of the Chief of Sanitation. In Yap, agreement was readily



Rota-loo installed and operating at the Yap Institute of Natural Science.

reached to the Greenpeace suggestion that it be sited at the Yap Institute of Natural Science, where the toilet would be used primarily by three full-time employees and occasional visitors. A second demonstration site was also selected at the home of a YapCAP employee on a site that was unsuitable for a septic system.

Follow-up workshops were held in November/December 1992, after completion of the units, and again in September 1993.

YINS Rota-Loo

The first installation of a commercial biological toilet at the Yap Institute of Natural Sciences (YINS) was begun immediately after the workshop on Yap, in March 1992. The model used was a Rota-Loo, manufactured in Australia, which had been recently salvaged after use in Greenpeace's Antarctic research base.

The Rota-Loo uses a four-chambered fibreglass waste collection tank for batch digestion, which rotates on a pivot. One chamber is located directly below the toilet pedestal and filled over the course of several month's usage. When it is filled, the tank is rotated so that this first chamber is isolated from fresh wastes, and the next chamber is positioned below the pedestal. After all four chambers have been filled, about a year with recommended usage, the waste in the first chamber is completely digested into humus and may be removed so that the chamber is ready to be used again. Because it was designed primarily for home installation in temperate climates, the Rota-Loo requires forced ventilation from an electric fan and is equipped with an electric heater to maintain proper temperatures for microbial activity.

The installation was accomplished by a YapCAP work crew under the supervision of Greenpeace, though final construction of the 'out-house' style room was not completed until later. The toilet was sited on an approximately 30 degree slope, so that the digestion tank could be located under the toilet room with only a slight excavation of the hillside. The original vent pipe no longer existed, so a spare length of ten centimetre (four inch) PVC drain waste and vent (DWV) pipe was substituted. In addition, a length of heavy PVC schedule 85 water main pipe was used to connect the toilet pedestal to the tank underneath. A 120-volt fan was provided to provide forced air ventilation. After the tank was put in place, a final workshop session was held to provide training in the start-up and maintenance of the Rota-Loo.

Installation was completed and operation of the unit begun in May.

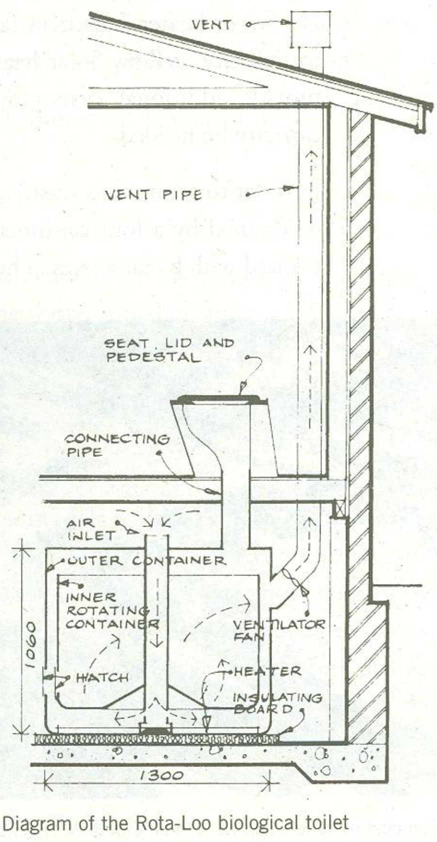


Diagram of the Rota-Loo biological toilet

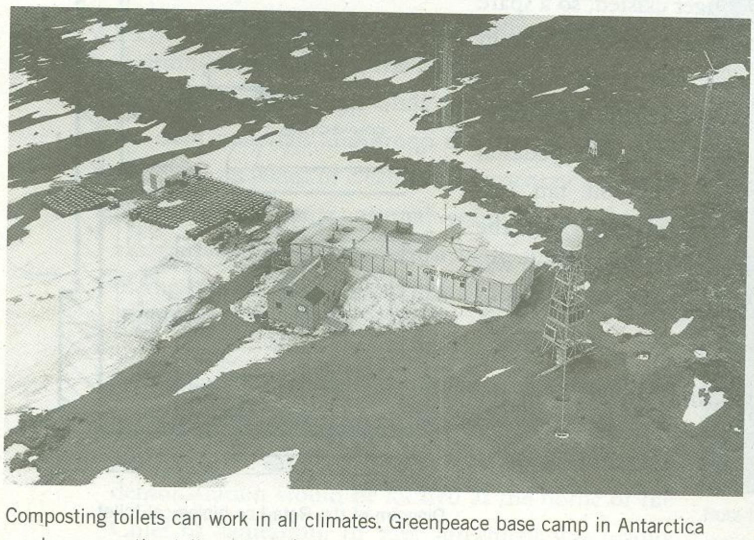
Greenpeace Prototype

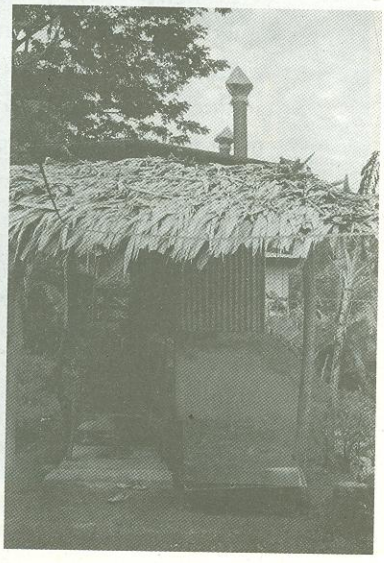
In June, 1992 work began on a prototype biological toilet designed by Greenpeace to be constructed of materials commonly available on Yap and not to require electricity. It is primarily made of locally manufactured cement block and poured concrete slabs, and uses discarded fishing nets in an innovative way of separating the composting wastes from accumulating liquids in the digestion tank. Like the Rota-Loo, the Greenpeace prototype is a batch composter. But rather than utilising rotating chambers, it contains two compartments positioned side-by-side. When one compartment is filled, it is closed off and the other one is used, while the waste material in the first finishes composting. By the time the second one is filled, the humus is ready for removal from the first compartment so that it may be used again, while the material in the other one digests. Each compartment is designed to be filled in approximately six months when used by a family of ten.

This design is a modification of the ventilated improved pit latrine (VIP) which has been used in Africa and elsewhere. While the VIP relies primarily upon anaerobic digestion, the Greenpeace prototype is designed to encourage aerobic bacteria. This is accomplished by suspending the solids on a false floor made of woven coconut palm fronds sitting on a nylon fishing net which is hung within the digestion chamber, and by greatly increasing the ventilation. Although the woven mat decomposes during the composting process, this takes sufficient time to allow the drying and biological processes to 'knit' the amorphous waste materials together so that they would not fall through the net. To further enhance evaporation, wicks made out of strips of polyester or rayon fibre, are hung from the net to the liquid below, exposing more surface area to the air stream.

No fan or heater is used. A fairly large, 20 centimetre (eight inch) diameter vent pipe is used to enhance airflow. Solar heat from a simple collector can be added to the incoming air to provide additional evaporation and increase process temperatures should additional user capacity be needed.

In order to assure zero waste water discharge, any liquid not evaporated in the reactor tank can be drained by a four centimetre (1.5 inch) pipe into a sealed, aerated evapotranspiration bed planted with banana trees. The aerated sand and gravel bed supports aerobic soil bacteria which





Composting toilets can work in all climates. Greenpeace base camp in Antarctica used a composting toilet. Right the Greenpeace composting toilet for the tropics.

> **Plans of the Greenpeace biological toilet are available from:**
>
> Greenpeace Pacific
> Private Mail Bag
> Suva, Fiji

will transform the organic and inorganic solids in the liquid into nutrients that can be assimilated by the roots of the banana tree for growth and transpire any remaining water from the broad leaves. A non-edible banana species on the property was identified for this purpose. However, as further described below, there has never been any discharge from the system.

The site chosen for the Greenpeace prototype is beside a new home being constructed by a YapCAP employee, in the village of Chool in the Maap Municipality. He had originally planned to build a septic system, but the water table was found to be too high. Upon digging the hole for the leach field, it filled with water. The unsuitability of the location for a septic system made it an ideal site for the demonstration of zero-discharge waste technology. In addition, the high-caste status of the owner may add to the social acceptance of the technology within the village.

The ground water at the site rises during normal rainfall up to ground level, dictating an above-grade level construction to avoid having the biological toilet tank flooded. Installation was completed and operation begun in early 1993.

Kosrae Vera Carousel

In Kosrae, Greenpeace arranged for the Norwegian manufacturer, Vera Fabrikker, to donate one of its biological toilets. Because of shipping delays, installation was not begun until August. The Vera 'Carousel' toilet is of a similar design to the Rota-Loo used in Yap, although the model used in Kosrae has a larger capacity. It was placed next to the home of Katsuo William, chief of the Division of Sanitation within the Department of Health. Because ground water was not a problem at the site selected, the carousel reactor was placed on a below-grade foundation with a poured cement floor in order to permit ground level access to the toilet room.

Installation was finished in December, and operation commenced 1 January, 1993.

Operation

For start-up, a substrate is prepared in the digestion chamber to allow proper drainage of liquids and to provide the soil bacteria which digest the waste. A bed of small rocks and gravel along with chunks of coconut husk are placed in the Rota-Loo and Vera units to prevent the drain holes in the bottom of the inner chamber from clogging. A mat of coconut leaves is placed on the fishing net in the Greenpeace prototype. Then a scoop of rich garden soil provides the necessary microorganisms.

Aside from normal cleaning, each of the demonstration models require a minimum of routine maintenance to ensure proper conditions for aerobic digestion to take place. Primarily, this consists of adding a small amount of organic matter after each use to provide both a source of carbon for the aerobic bacteria as well as a spongy-texture allowing air to penetrate that mass. There is a great abundance of appropriate material in Micronesia to serve this purpose including leaves and shredded coconut husks. The user simply drops a handful of material into the toilet after each use. In addition, the digestion chamber must be periodically checked and rotated when full (compartments changed with the Greenpeace prototype). After all chambers are filled, the humus in the fully digested chamber is removed.

Results and Conclusions

The biological toilet installed at the Yap Institute of Natural Sciences has been visited by Greenpeace five times since it began operating in May 1992. The toilet was inspected for proper operation and the primary users interviewed to determine satisfaction in June, August and November 1992, September 1993, and October 1994. On each occasion, no odour was detected and the users expressed no complaints. The toilet room has been kept clean and no flies have been found inside. The electric fan has run continuously except for occasional power failures in Kolonia's utility system. During an extended period of daily power outages while a generator was being repaired in 1994, some liquid build-up was experienced, and it was assumed that this was caused by inadequate ventilation due the fan not running.

The electric heating units contained in the digestion tank have not been used. A variety of materials have been used for the necessary organic additive including several different kinds of leaves and shredded coconut husks.

When interviewed in June 1992, the Institute's director explained that during the first several weeks of use, there was an occasional odour to which she responded by increasing the amount of organic material added after each use. No odours have been noticed since that time. The users seem quite satisfied with the toilet's performance. The Institute's director reports that on several occasions they have been visited by neighbours who seem to have come primarily to use the biological toilet.

Observations suggest that the Micronesian climate has significantly enhanced the performance of the treatment process over what is typically experienced in temperate climates. Although all of the chambers of this small version of the Rota-Loo would be expected to be filled after a year's use in Australia, this process took 2 ½ years in Yap.

The first chamber of the digestion tank was determined by the Institute staff to be full in August after four months of use, although it had not actually reached its capacity. Visual inspection through the access hatch in November revealed that the composting process was occurring as expected, with a gradient of more highly decomposed to less digested material from bottom to top of the chamber. The composting mass was quite dry and there was no accumulation of excess liquid at the bottom of the tank, indicating that the ambient temperature and ventilation have been adequate to accomplish evaporation. Subsequent chambers were filled to capacity over greater periods of time, such that the fourth one was found to be full in October 1994. By this time, material in both of the first two chambers appeared to be completely decomposed.

The owner of the Greenpeace prototype was interviewed periodically since use began in January 1993, and site visits were conducted in September 1993 and October 1994. He and all family members expressed satisfaction with the operation of the unit. No foul odours have ever been a problem. The unit is kept very clean, and a number of modifications have been added to the structure to enhance its comfort and appearance, including a chair on the porch-like landing providing access to the two toilet entry rooms.

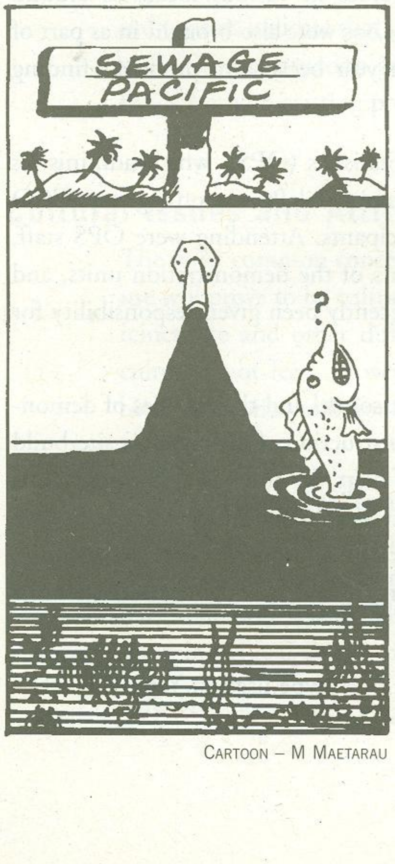
Visual inspection of the first digestion chamber indicated no excess liquid. Although the hanging net may not have been positioned quite properly, allowing some of the solids to fall through to the chamber floor, this material was relatively dry and appeared to be undergoing biodegradation. After nine months of operation, the first chamber was only partially full in September, 1993. Although use was switched over to the second chamber sometime in early 1994, subsequent inspection in October revealed that it had not yet reached capacity. The material in the first chamber did, however appear to be nearly fully decomposed.

When last interviewed in May 1994, the owner remained very enthusiastic about the performance of the Greenpeace Prototype, and was assisting with another biological toilet demonstration project being conducted on Pohnpei. Tragically, he was killed in a freak accident while diving for trochus in June. His family has moved, the toilet has not been used very much since that time and future use and maintenance remain uncertain.

The Vera Carousel toilet on Kosrae has been inspected by Greenpeace on two occasions subsequent to the start of use. Observations indicate that, as with the other units, the higher ambient temperature of Micronesia has greatly extended its capacity over that specified by the manufacturer of the Carousel when used in a temperate zone. This correlates with increased capacity data reported from the manufacturer of the solar heated compost system (SOLTRAN™) which has used the Carousel as a compost reactor and raises temperatures from 21° to 54° C while maintaining a 50-80% moisture content of the biomass.

As of October, 1994, after nearly two years of use, only two of the four chambers in the digestion tank had been used. In fact, although the carousel was shifted away from the first chamber in mid-1994, it does not appear that it was close to being full. In part, this is due to the fact that there are only four to five people regularly using the toilet, however, this factor is not by itself enough to explain the length of time needed to fill the unit.

Periodic telephone interviews with Mr William and his family and in person during site visits indicate that they have been happy with the unit. Mr William has stated that he recommends it to all who inquire. In the early months of operation, a radio announcement invited everyone to come see and use the toilet, so he was able to assess public opinion. Everyone was surprised that there was no smell as they expected since there is no water seal as with conventional water closets.



Cartoon – M Maetarau

Further discussion revealed that on occasion, a slight musty odour could be detected, although this was not objectionable. This was likely to be due to the fact that the removable, in-line fan motor and blade which was installed in the vent pipe was only turned on when the toilet was used. Because this in-line fan can block the air flow up the vent pipe, it was suggested that it be removed to allow natural convection currents to move air without the fan. As a further measure, the height of the exhaust pipe could be increased. However, the fact that the odour which has been noticed was not strong suggests that some airflow is occurring even with the blockage caused by the fan when it is not in use.

There is generally no excess liquid in the tank, indicating that there is usually sufficient heat from the ambient air flow to evaporate the excess liquid for the number of users without considering additional heat sources such as solar energy or draining it to a sealed evapotranspiration bed. However, during cooler and wetter periods, some excess water is detected. In response, the auxiliary electric heater provided with the unit is turned on for a day or so until the liquid is evaporated. Several factors may contribute to less than optimum air-flow, including an inadequately sized insect screen at the top of the ventilation pipe. Because screens restrict air-flow, it is recommended that they be installed in a way that increases the surface area, which was not done in the Kosrae toilet. It is possible that this, in combination with a blockage of airflow by the fan when not in operation as described above, may cause the occasional build-up of excess liquid in the digester.

In addition to the project's success at demonstrating the viability of waterless biological toilets in Pacific island countries, as evidenced by the satisfaction of each of the demonstration hosts and the visual observations that the systems have been functioning properly, it has also succeeded in stimulating interest in the technology from local officials. In Yap, the Community Action Program has modified the design of the Greenpeace Prototype toilet and is making them available for use by recipients of a low-interest housing loan program. In addition, there are plans to install biological toilets in 16 Head Start pre-school centres on Yap's outer island atolls. In Kosrae, a biological toilet is being installed in a government weather monitoring station, and has been chosen for use in a planned visitor facility in a Marine Park. Also, interest has been expressed in their use as an alternative to septic systems being installed in Kosrae's villages.

Centre for Clean Development Pohnpei Project

As a result of the success of the Greenpeace project on Yap and Kosrae, the FSM national government asked the Centre for Clean Development (CCD) to conduct an expanded project on the island of Pohnpei to demonstrate biological toilets and greywater gardens for the management of washwater in 1994. Four site-built concrete 'Greenpeace prototype' toilets and one Greywater Garden™ were constructed at private homes in various locations around Pohnpei. In addition, two large capacity commercial Rota-Loos were also brought in as part of the project but had not been installed by the end of the year because of problems finding appropriate recipients.

Working closely with the FSM Office of Planning and Statistics (OPS), which administers several rural sanitation projects funded by the US Environmental Protection Agency, CCD held a training workshop in May 1994 for project participants. Attending were OPS staff, representatives of other government agencies, the recipients of the demonstration units, and staff from the Pohnpei Utilities Corporation, which has recently been given responsibility for providing water and sewer services for Pohnpei State.

Following the workshop, work crews consisting of OPS personnel and the families of demonstration recipients under the supervision of CCD began construction of the concrete site-build biological toilets at four locations in the municipalities of Nett, U, and Kiti. All of the units were completed and became operational within the next several months. One grey water garden was also begun, but unfinished. In addition, personnel from the Pohnpei Utilities Corporation who had been trained in the workshop, constructed two demonstration units within an outer island settlement in Kolonia.

The biological toilets were very similar to the Greenpeace Prototype used in Yap, with a few minor modifications, and function in the same way. As in Yap, they were all installed with the digestion chambers above ground, necessitating a short staircase to enter the toilet room positioned on top.

In October CCD conducted a follow-up workshop for project participants and visited three of the four demonstration sites to interview host families. All of the users expressed great satisfaction and no odour was present at any of the units. Visual inspection of the units indicated that all were being well maintained and that the composting process seemed to be occurring as expected. Although the somewhat strange appearance of the toilets had at first aroused the curiosity of neighbours, each of the families reported that their neighbours now wanted one. Neither of the two toilets constructed by the Pohnpei Utilities Corporation were operational in October, reportedly only lacking the installation of fishing net in the digestion chambers as called for in the design.

Also in October, the incomplete Greywater Garden™ was finished and began operation for the treatment of wastewater from a clotheswashing machine, which had formerly discharged into an adjacent stream. The garden bed was covered with an extension of the roof overhang from the small shack containing the washing machine. It consists of a three-metre (ten-foot) long trench, which is 45 centimetres (18 inches) deep and 45 centimetres (18 inches) wide, filled with a 15-centimetre (six-inch) layer of gravel and 30 centimetres (12 inches) of sand on top, and ventilated as described previously in this report. A variety of plants found growing around the surrounding property in standing water or saturated soils were transplanted into the trench, including reeds, members of the ginger family, hibiscus, and water hyacinth. All plants reportedly appeared healthy and the garden was functioning as designed after one month of operation.

As with the previous Greenpeace project on Yap and Kosrae, the CCD project has demonstrated the successful operation of biological toilets in Micronesia. Additionally, preliminary indications indicate that greywater gardens can be useful in managing domestic wastewater as well. The construction grants manager at OPS has indicated his intention to use remaining funds from an existing project to build at least 40 more biological toilets in Pohnpei state.

Cultural Issues and Attitude Changes

The most common concern expressed about waterless biological toilets is whether or not their use will prove to be culturally compatible. It is important to note that there is embarrassment, reluctance and other difficulties in dealing straight-forwardly with human excreta in most cultures, not least in western industrialised countries. This is often cited as a reason why biological toilets will not succeed, since they depend upon individual users to perform routine maintenance.

Clearly, biological toilets must have regular care or they will fail. However, all sewage treatment technologies require maintenance. Conventional solutions tend to centralise this function with engineers, who typically resist alternatives that would distribute this responsibility to individuals. The widespread failure of conventional centralised technologies suggests that relying upon individual users is no more problematic than a centralised approach.

Any technology must be planned and used in a way which fits the local culture. The design of a program for widespread introduction of biological toilets will have to take these factors into account. During the course of the two projects, several socio-cultural issues were identified which need to be further investigated if the technology is to become widely used. For example, it was noted that after the first three months of operation in Kosrae, none of the women in the family had yet used the biological toilet. A telephone interview revealed that although enclosed by walls and a roof, the toilet may be a bit too close to the main house and 'public,' causing the women to feel too embarrassed to use it. However, this phenomenon was only temporary, and may also be related to the newness of the technology. Apparently, a similar initial reluctance among some Kosraean women was said to have occurred when water seal toilets were first introduced, although this has since disappeared. Major issues to be addressed in Micronesia include:

- A general lack of attention to maintenance of modern material possessions in urban areas;
- Preference by some groups to use the forest or beach rather than toilets;
- Various taboos regarding human excrement within the individual cultures of the region. For example, in Yap, the subject is not normally brought up in conversation. No one asks permission to 'go to the bathroom', or announces this intention in any way. According to one source, certain taboo areas which are said to be inhabited by evil spirits may have their origin in being commonly used for defecation. For these reasons, any highly visible locations for toilet facilities are unlikely to succeed.
- Strict gender-related rules in some cultures for carrying out daily activities within a family. In the Yap outer islands, a brother and sister cannot eat with the same utensils, and would not be able to use the same toilet facilities.

While cultural issues must be addressed and attitudes toward human excrement changed if biological toilets are to be widely used, these tasks are by no means prohibitive. Indeed changing attitudes is central to solving most environmental problems, and a great deal of emphasis is already placed upon public educational programs to achieve them. The prospect of changing human behaviour may appear daunting to officials charged with the responsibility to solve sanitation problems, particularly if they have been primarily trained to work with pipes and machines rather than people. But given the failings and expense of the conventional approach to sewage problems, addressing the behavioural issues needed to make the alternatives work may be far cheaper and easier.

Recommendations

This report has attempted to present a picture of the extent of sewage pollution problems in the Pacific region within the limits of available data and to document the failings of conventional technologies to solve them. But these problems are not necessarily intractable, as the previous two sections have shown. It is possible to prevent sewage pollution, and to do so at a far lower cost than continuing conventional efforts to simply control it. More specifically, the following recommendations are presented as a policy for preventing sewage pollution in Pacific Island Developing Countries.

Policy Guidelines

Greenpeace believes that policy addressing sewage pollution should be based on the following guiding principals, which can also serve as criteria for the selection of sanitation technologies:

Zero Discharge

Despite the commonly accepted notion of the capacity of the environment to assimilate dilute amounts of sewage, the widespread record of sewage pollution problems suggests that this is difficult to predict, if it is true at all. In addition, the experience worldwide with the conventional approach to pollution, based on controlling it to 'acceptable levels', reveals that it is a practical impossibility for Pacific Island Developing Countries. Even assuming that the impacts of a given sewage discharge can be adequately understood and permissible levels set, the cost of conventional collection and treatment technologies and the regulatory framework – the monitoring and enforcement – required to ensure environmental protection is far beyond the capacity of island nations to sustain.

The only way to ensure protection of the marine environment and fresh water resources is a policy of zero-discharge, based on the precautionary principal. Given the high value of these resources and the significant risk that they will be impaired by sewage discharges, the goal of zero discharge is justified. This is particularly the case in view of the fact that this can be practically and cheaply achieved. There is no good reason to allow any pollution discharge to the environment when it is preventable. This approach also reduces the costs of monitoring and enforcement, since the collection of samples and laboratory analysis is not required.

Recovery of Excreta as a Resource

The way to achieve zero discharge is through the recovery of excreta and its conversion into a product of value, rather than disposing of it as a waste. Human excreta contains nutrients which can be converted by living systems into useful forms, such as fuel or fertilisers, while preventing direct contact with disease causing organisms. As described elsewhere in this report, there are a number of practical technologies which can accomplish this.

Avoid The Use of Water

The use of water for the transport of human excreta and domestic wastewater must be eliminated. Waterborne treatment systems are expensive, waste valuable fresh water resources, and inevitably lead to pollution. The collection and transport of sewage accounts for 70-90% of the costs of a conventional waterborne sewage system. Increasingly scarce fresh water supplies are too valuable to flush down the toilet. Sewer pipes all eventually leak, causing groundwater contamination, and sewage treatment plants can not remove all of the pollutants from wastewater prior to discharge.

Disinfection Without Chlorine

Because treatment of sewage effluent with chlorine-containing chemicals causes the formation of many toxic, carcinogenic compounds, it should not be used for disinfection. Alternatives, such as oxygen based disinfectants or ultraviolet light, should be used instead.

Prohibit Industrial Waste

The mixing of industrial waste with human excreta and domestic wastewater should be prohibited. Industrial waste is not effectively detoxified by conventional sewage treatment technologies or alternative ecologically engineered systems. The presence of toxic heavy metals and organic chemicals renders sewage unfit for recovery as fertiliser or fuel. In addition, the presence of toxic chemicals can inhibit any biological treatment process by killing the microorganisms which perform the work.

Existing Water-Based Systems

In addition to the those listed above, several measures can be taken to reduce the amount of pollution discharged from existing conventional sewage treatment systems.

Water Conservation

The efficiency of the removal of pollutants by conventional sewage treatment plants can be enhanced by reducing the amount of water in sewage. There are a wide variety of well-proven water-saving technologies including low-flush toilets, low-flow sink faucets and showerheads, efficient clothes washing machines and dishwashers. If used throughout the service area together with water conservation strategies designed to eliminate unnecessary water use, the flow of wastewater to a sewage treatment plant can be greatly reduced. In addition to improving the quality of effluent, water conservation can also extend the capacity of existing treatment plants to handle increasing populations, potentially making the construction of new treatment plants unnecessary.

Conversion and Beneficial Use of Sludge

When free of toxic chemicals, the sludge produced through primary and secondary treatment processes can be used as a valuable soil conditioner after composting.

Wastewater Reuse

Secondary or tertiary treated sewage effluent can be used for irrigation on landscaping and some agriculture in circumstances where groundwater and coastal resources are not threatened.

Supplemental Treatment Using Ecologically Engineered Technologies

The quality of sewage effluent can be greatly improved at relatively low cost by adding ecologically engineered technologies such as those described in this report to the end of an existing treatment process. Also, existing treatment works can in some cases be converted to, or used as a portion of, these alternative systems.

Pacific Input Toward International Action

The current process leading up to the UNEP-hosted Intergovernmental Conference on the Prevention of Marine Pollution from Land-Based Activities scheduled to take place in Washington, DC, in November 1995, offers an opportunity to institutionalise the policies outlined above. However, so far the agreement being drafted does little to encourage specifically the prevention of sewage pollution or to facilitate the use of alternative, zero-discharge technologies. Rather, the strategy for addressing sewage pollution relies primarily on expanding the failed conventional approach.

Pacific island nations have already provided meaningful input to the process. For example, the government of Kiribati has noted in comments to UNEP 'That existing mechanisms for the control of land-based sources of marine pollution have not been sufficiently effective.'[72] Also, SPREP has coordinated the development of a paper offering regional input to UNEP which includes many important suggestions for achieving pollution prevention, such as demonstration projects and funding mechanisms.[73]

As noted elsewhere in this paper, Pacific Island Developing Countries have been instrumental in achieving existing international measures to protect the marine environment, such as the international ban on ocean dumping in the London Convention. This same kind of active role in the negotiations leading up to the Washington Conference will be necessary if current efforts are to produce effective results.

Regional Action

The South Pacific Regional Environment Programme has increasingly embraced the concept of pollution prevention in its words. For example, this approach is reflected in most of the objectives contained in the SPREP 1991-1995 Action Plan, Programme 5: Prevention and Management of Pollution, which include the development of 'technical, legal, and administrative measures for prevention and management of waste,' to 'minimize the amount of waste and maximize the recycling of waste products...,' and to 'provide a clearinghouse for, and encourage use of, production processes and technologies which minimise waste generation.' In addition, the SPREP is now armed with a 1994, South Pacific Regional Pollution Prevention and Waste Management Programme, which outlines specific measures for achieving these goals.

However, SPREP has yet to implement these measures, and the limited activity on pollution which is conducted has tended to focus on seeking improvements in the disposal and control of wastes rather than prevention. To be fair, SPREP has been hampered by a lack of funds dedicated to this area. But effective action from SPREP is essential if sewage pollution, widely acknowledged to be among the most widespread and serious problems in the region, is to be adequately addressed.

With regard to sewage, important regional action includes:

- training and technical assistance on ecologically engineered zero-discharge sanitation technologies;
- demonstration pilot projects of these technologies;
- establishment of the Pollution Prevention Trust Fund and other mechanisms to fund and finance zero-discharge systems.

National and Local Action

While Pacific island governments all identify pollution from sewage as one of the primary threats to the natural resources and public health in their countries, the solutions they propose would not adequately address these problems. By and large, almost all national and local governments continue to seek control and disposal options rather than implement prevention oriented measures. The National Environmental Management Strategies (NEMS) developed under the coordination of SPREP by most Pacific island countries in recent years are a case in point. With a few exceptions, notably the Cook Islands and Kiribati,[74] the specific programmes of action which they identify generally rely upon failed conventional approaches.

The Marshall Islands NEMS offers a prime example. The two goals of the strategy regarding sewage are to: 'improve sewerage disposal infrastructure in both urban and rural areas' and to 'raise public awareness of environmental issues stemming from improper disposal of sewerage.' While they may at first appear laudable, further consideration reveals that even achieving them will not adequately address the country's sewage pollution problems.

The primary programme measure outlined in the strategy is to simply expand a disposal infrastructure which itself is a major source of pollution. The Marshalls NEMS Program 4.1 Expanding Sewerage Capital Works, reads as follows:

> *1) To construct water-seal toilet facilities at all public schools presently lacking them; 2) to construct sewerage hook-ups at the two docks on Majuro and one dock on Ebeye, so that ships in port can access the public sewer system; 3) to purchase sewage trucks for Majuro and Ebeye which can be used to transfer waste from septic tanks to the public sewage system; 4) to provide technical assistance to outer atoll communities for construction of toilets for each household.*

While these measures may partially address the public health danger of direct contact with human faeces, and perhaps also result in the transfer of sewage pollution from one location to another, they do not solve the problem. Constructing water-seal toilets at schools will only provide a more direct route for sewage pollutants into the groundwater. Sewerage hook-ups for ships while in port could result in reducing sewage contamination in harbour areas, but it may also end up transferring it to the site of the sewage treatment outfalls. Pump trucks are necessary to remove sludge from existing septic systems, however, they will not eliminate the seepage of pollutants into underground water from even properly operating septic systems, nor will they ensure that the septage will be rendered harmless when transferred to the public sewer system. Finally, assisting outer atoll communities to construct conventional toilets for each household may only exacerbate pollution problems and would waste scarce fresh water.

Another example is provided by the Federated States Of Micronesia NEMS. While sewage pollution is well described and identified along with solid wastes as 'one of the most trouble-some environmental problems' of the country, the only program addressing sewage is a public education program. Even more astonishing is the fact that the NEMS of the Solomon Islands does not have a single programme addressing sewage pollution, despite the acknowledged problems this is causing in the country.

As those primarily responsible for providing sanitation, infrastructure and the regulation of pollution in Pacific island countries, national and local governments must take the lead role in changing the approach to sewage pollution. Even though they may not have the resources or the technical expertise to do this on their own, they must critically evaluate the technical assistance provided through bilateral aid programmes, development agencies and lending institutions to determine if the approaches offered will truly solve pollution problems or simply shift them around. Unfortunately, much of the advice offered by the experts from industrialised countries is based on inappropriate conventional approaches. Technical assistance should help Pacific Island Developing Countries avoid mistakes which have already been made, not ensure that they are repeated.

This report has shown that sewage pollution can be prevented with a new approach and modern, though simple and low-cost, technologies. When local and national officials understand that pollution is not an inevitable price of progress, and insist upon real solutions and true sustainable development, then sewage pollution will be prevented, and the resources of the region and the health of its people protected.

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GREENPEACE

GREENPEACE PACIFIC
Private Mail Bag
Suva, Fiji
Ph (679) 312 861
Fax (679) 312 784
E-mail address:
greenpeace@pactok.peg.apc.org