12. Public health, hygiene and waste disposal

SUMMARY

The numbers are staggering. An estimated six million people worldwide contract a food-borne illness each year. It is not just the person infected with the illness that suffers. Damage of food-borne illness to an operation can include loss of customers, reputation and sales. A fishery is a food producing operation and fish is a highly perishable product. The fishing harbour is the focal point of the fishing effort (and sometimes the village life revolves around the activities of the fishing harbour) and it is here that fish is likely to be contaminated.

What is contamination and what constitutes pollution are commonly asked questions and the view taken by some scientists is that a distinction must be made between contamination and pollution. Contamination is the presence of elevated concentrations of substances in the environment that are above the natural background level for the area and for the organism. Pollution on the other hand is the introduction by humans, directly or indirectly, of substances or energy into the water, resulting in such deleterious effects as harmful to living resources and hazard to human health.

Therefore, this chapter deals exclusively with the environment within a fishing port, such as water quality standards, personal hygiene, sewage treatment and disposal, and waste reception facilities and disposal. The objective is to have health, hygiene and waste disposal issues addressed by port planners when designing new ports and upgrading existing facilities as well as by port managers at all times. Thus, the standards for sanitary water that should be used in all aspects of fisheries, including the routes of contamination, are reviewed and solutions proposed. In particular, methods for the disposal of all types of waste likely to arise from fishing operations are discussed.

Consequently, the readership, port engineers, port managers and those responsible for safety and health would be better equipped to design systems that can withstand the rigours of a new modern fishing port and, with regard to existing fishing ports, to identify potentially weak points in their public health applications as well as waste disposal systems. The ultimate beneficiaries will be the consumers of fish and fish products.

CONTENTS

12.1 HAZARD ANALYSIS AND CRITICAL CONTROL POINT PROGRAMME

By charting the flow of fish through the fishing harbour (from the time it is discharged on the quay to the time it leaves the port boundary), points can be identified where contamination or growth of micro-organisms occur. Control features can then be implemented based on the identified health hazard. This technique is known as a Hazard Analysis and Critical Control Point programme or HACCP in short. To the fishing port planner, the three major areas of concern are:

- water quality standards of all the water used in the port (potable and seawater);
- personal hygiene of the shore-based workers; and
- standard of cleanliness of the port in general.

Under HACCP, these three areas of concern translate into drastic changes in the long term. In particular, these involve:

- minimizing and eventually eliminating harbour and coastal pollution from point and non-point sources;
- improving sanitation and hygiene throughout the fishing harbour; and
- maintaining port and harbour infrastructure in good working order.

In order to comply with these directives, a fishing port planner needs to have a good understanding of both the natural environment existing around the fishing harbour as well as the environment generated within the harbour's infrastructure and with it the wastes generated by the various components of the fishing effort.

This chapter deals exclusively with the environment within the fishing harbour, such as water quality standards, personal hygiene, sewage treatment and disposal, and waste reception facilities and disposal.

12.2 WATER QUALITY STANDARDS

Water is the underlying link which connects the various fishing activities together, such as harvesting, storing and icing on board, handling inside a harbour and eventual sale to consumers. Assuming that fish is generally caught offshore in relatively pollution-free waters, potable water, and hence ice, come into contact with it all the way down the process in port, right up to the fish vendor's market stall.

Generally speaking, most fishing harbours are connected to an approved mains supply: in some developing countries, however, the water is supplied from local resources such as lakes, rivers or underground aquifers which may or may not be contaminated. This fact alone makes it vitally important for a fishing harbour planner to understand water quality standards, the types of pollutants which may be present in the water supply and the most likely sources for these pollutants. Also, due to the acute shortage of potable water in and around some fishing harbours in many developing countries, raw seawater (i.e. drawn from within the harbour basin) often replaces freshwater in the shore-based activities, implying that, in addition to freshwater, harbour basin or estuary waters has also to be tested for contaminants.

Contamination of water by physical and bacteriological agents may be evaluated by laboratory tests. Test results are usually expressed in parts per million (*milligrams per litre or simply* ppm) or parts per billion (*micrograms per litre or* ppb) for physical parameters and bacterial counts per 100 millilitres for organisms. For both types of contaminants, maximum levels are usually stipulated and these levels may differ from country to country. The major contaminants of concern in potable water supplies are:

- suspended solids;
- biodegradable organics (proteins, carbohydrates and fats);
- pathogens;
- nutrients (nitrogen, phosphorus and carbon);

- priority pollutants (highly toxic chemicals);
- refractory organics (pesticides, phenols, surfactants);
- heavy metals; and
- dissolved inorganics (nuisance chemicals).

12.2.1 Suspended solids

The presence of suspended solids in water gives rise to turbidity. Suspended solids may consist of clay, silt, airborne particulates, colloidal organic particles, plankton and other microscopic organisms. The presence of particulate matter in water, whether organic, inorganic or due to higher micro-organisms, can protect bacteria and viruses from the action of disinfectants. The adsorptive capacity of some suspended particulates can lead to entrapment of undesirable inorganic and organic compounds present in the water and in this way turbidity can bear an indirect relationship to the health aspects of water quality. Airborne particulate matter is of particular concern to facilities located near mineral stockpiles (coal, iron ore, bauxite, etc.) or downwind from large power stations (fly ash), timber saw mills (saw dust) or cement factories (cement dust). Rainwater collection systems are particularly sensitive to such airborne particulates because they usually augment local potable water systems and act as conduits for the pollutants to enter the potable water system. Large quantities of aromatic hydrocarbons are also generated by the combustion of fossil fuel in oil-fired power stations and industrial kilns.

12.2.2 Biodegradable organics

Composed principally of proteins, carbohydrates and fats, biodegradable organics are measured most commonly in terms of biological oxygen demand (BOD). BOD is the quantity of oxygen required for the oxidation of organic matter by bacterial action in the presence of oxygen. The higher the demand for oxygen (the more organic the pollution), the less oxygen is left to support life. Urban sewage commonly has a BOD of 500 mg/litre. Harbour basin water should have a BOD in the range of 50 to 150 mg/litre.

12.2.3 Pathogens

The most common and widespread danger associated with drinking water is contamination, either directly or indirectly, by sewage, by other wastes, or by human or animal excrement (Table 1). If such contamination is recent, and if among the contributors there are carriers of communicable enteric diseases, some of the living causal agents may be present. The drinking of water so contaminated or its use in the preparation of certain foods may result in further cases of infection. Natural and treated waters vary in microbiological quality. Ideally, drinking water should not contain any micro-organisms known to be pathogenic to humans. In practice, this means that it should not be possible to demonstrate the presence of any coliform organism in any sample of 100 ml.

12.2.3.1 Bacteria

Faecal pollution of drinking water may introduce a variety of intestinal pathogens – bacterial, viral and parasitic – their presence being related to microbial diseases and carriers present at that moment in the community. Intestinal bacterial pathogens are widely distributed throughout the world. Those known to have occurred in contaminated drinking water include strains of *Salmonella, Shigella,* enterotoxigenic *Escherichia coli, Vibrio cholerae, Yersinia enterocolitica* and *Campylobacter fetus.* These organisms may cause diseases that vary in severity from mild gastroenteritis to severe and sometimes fatal dysentery, cholera or typhoid.

TABLE 1
Infectious agents potentially present in drinking water contaminated by sewage

Organism	Disease	Remarks
Bacteria		
Escherichia coli	Gastroenteritis	Diarrhoea
Legionella pneumophila	Legionellosis	Acute respiratory illness
Leptospira (150 spp.)	Leptospirosis	Jaundice, fever
Salmonella typhi	Typhoid fever	High fever, diarrhoea
Salmonella (~1700 spp.)	Salmonellosis	Food poisoning
Shigella (4 spp.)	Shigellosis	Bacillary dysentery
Vibrio cholerae	Cholera	Extremely heavy diarrhoea
Yersinia enterolitica	Yersinosis	Diarrhoea
Viruses		
Adenovinus (31 types)	Respiratory disease	
Enteroviruses (67 types)	Gastroenteritis, meningitis	
Hepatitis A	Infectious hepatitis	Jaundice, fever
Norwalk agent	Gastroenteritis	Vomiting
Reovirus	Gastroenteritis	
Rotavirus	Gastroenteritis	
Protozoa		
Balantidium coli	Balantidiasis	Diarrhoea, dysentery
Cryptosporidium	Cryptosporidiosis	Diarrhoea
Entamoeba histolytica	Amoebic dysentery	Prolonged diarrhoea with bleeding
Giardia lamblia	Giardiasis	Mild to severe diarrhoea, nausea
Helminths		
Fasciola hepatica	Fascioliasis	Sheep liver fluke
Dracunculus medinensis	Dracunculosis	Guinea worm
Ascaris lumbricoides	Ascariasis	Roundworm
Enterobius vericularis	Enterobiasis	Pinworm
Hymenolepis nana	Hymenolepiasis	Dwarf tapeworm
Taenia saginata	Taeniasis	Beef tapeworm
Taenia solium	Taeniasis	Pork tapeworm
Trichuris trichiura	Trichuriasis	Whipworm

The modes of transmission of bacterial pathogens include ingestion of contaminated water and food. The significance of the water route in the spread of intestinal bacterial infections varies considerably, both with the disease and with local circumstances. Among the various water-borne pathogens, there exists a wide range of minimum infectious dose levels necessary to cause a human infection. With *Salmonella typhi*, ingestion of relatively few organisms can cause disease; with *Shigella flexneri*, several hundred cells may be needed, whereas many millions of cells of Salmonella serotypes are usually required to cause gastroenteritis. Similarly, with toxigenic organisms such as enteropathogenic *E. coli* and *V. cholerae*, as many as 108 organisms may be necessary to cause illness. The size of the infective dose also varies in different persons with age, nutritional status and general health at the time of exposure.

The significance of routes of transmission other than drinking water should not be underestimated as the provision of a safe potable supply by itself will not necessarily prevent infection without accompanying improvements in sanitation and personal habits. Education in simple applied and personal hygiene is essential.

Surveillance of the bacterial quality of water is also important, not only in the assessment of the degree of pollution, but also in the choice of the best source and the treatment needed. Bacteriological examination offers the most sensitive test for the detection of recent and therefore potentially dangerous faecal pollution, thereby providing a hygienic assessment of water quality with a sensitivity and specificity that is absent from routine chemical analysis. It is essential that water is examined regularly and frequently as contamination may be intermittent and may not be detected by the examination of a single sample. For this reason, it is important that drinking water is

examined frequently by a simple test rather than infrequently by a more complicated test or series of tests. Priority must always be given to ensuring that routine bacterial examination is maintained whenever human resources and facilities are limited. It must be appreciated that all a bacteriological analysis can prove is that, at the time of examination, contamination, or bacteria indicative of faecal pollution, could or could not be demonstrated in a given sample of water using specified culture methods. In addition, the results of routine bacteriological examination must always be interpreted in the light of a thorough knowledge of the water supplies, including their source, treatment and distribution.

Whenever changes in conditions lead to deterioration in the quality of the water supplied, or even if they should suggest an increased possibility of contamination, the frequency of bacteriological examination should be increased so that a series of samples from well-chosen locations may identify the hazard and allow remedial action to be taken. Whenever a sanitary survey, including visual inspection, indicates that a water supply is obviously subject to pollution, remedial action must be taken, irrespective of the results of bacteriological examination. For unpiped rural supplies, sanitary surveys may often be the only form of examination that can be undertaken regularly.

The recognition that microbial infections can be water-borne has led to the development of methods for routine examination to ensure that water intended for human consumption is free from excremental pollution.

Although it is now possible to detect the presence of many pathogens in water, the methods of isolation and enumeration are often complex and time-consuming. It is therefore impractical to monitor drinking water for every possible microbial pathogen that might occur with contamination. A more logical approach is the detection of organisms normally present in the faeces of humans and other warm-blooded animals as indicators of excremental pollution, as well as of the efficacy of water treatment and disinfection. The presence of such organisms indicates the presence of faecal material and thus that intestinal pathogens could be present.[1] Conversely, the absence of faecal commensal organisms indicates that pathogens are probably also absent. Search for such indicators of faecal pollution thus provides a means of quality control. The use of normal intestinal organisms as indicators of faecal pollution rather than the pathogens themselves is a universally accepted principle for monitoring and assessing the microbial safety of water supplies. Ideally, the finding of such indicator bacteria should denote the possible presence of all relevant pathogens.

Indicator organisms should be abundant in excrement but absent, or present only in small numbers, in other sources; they should be easily isolated, identified and enumerated and should be unable to grow in water. They should also survive longer than pathogens in water and be more resistant to disinfectants such as chlorine. In practice, these criteria cannot all be met by any one organism, although many of them are fulfilled by coliform organisms, especially *Escherichia coli* as the essential indicator of pollution by faecal material of human or animal origin.

Other micro-organisms described as “faecal coliforms” such as faecal streptococci and sulphite-reducing clostridia, especially *Clostridium perfringens*, that satisfy some of these criteria (though not to the same extent as coliform organisms) can also be used as secondary indicators of faecal contamination.

The significance that can be attached to the presence or absence of particular faecal indicators varies with each organism and especially with the degree to which that organism can be specifically associated with faeces. Coliform bacteria should not be detectable in treated water supplies, and if found, indicate inadequate treatment or post-treatment contamination.

[1] The human intestinal tract contains countless rod-shaped bacteria known as coliform organisms and each person discharges from 100 billion to 400 billion coliform organisms per day in addition to other kinds of bacteria.

Furthermore, coliform bacteria are derived not only from the faeces of warm-blooded animals but also from vegetation and soil. For these reasons, the presence of small numbers of coliform organisms (1 to 10 organisms per 100 ml), particularly in untreated groundwater, may be of limited sanitary significance provided faecal coliform organisms are absent.

When coliform organisms are found in the absence of faecal coliform organisms and *E. coli*, secondary indicators may be used to confirm the excremental nature of the contamination.

12.2.3.2 Viruses

Viruses of major concern in relation to water-borne transmission of infectious disease are essentially those that multiply in the intestine and are excreted in large numbers in the faeces of infected individuals. Concentrations as high as 108 viral units per gram of faeces have been reported. Even though replication does not occur outside living hosts, enteric viruses have considerable ability to survive in the aquatic environment and may remain viable for days or months. Viruses enter the water environment primarily by way of sewage discharges. With the methods available at present, wide fluctuations in the number of viruses in sewage have been found. On any given day, many of the 100 or so known enteric viruses can be isolated from sewage, the specific types being those prevalent in the community at that time.

Procedures for the isolation of every virus type that may be present in sewage are not yet available. As sewage comes into contact with drinking water, viruses are carried on and remain viable for varying periods of time depending upon temperature and a number of other less well-defined factors. It is generally believed that the primary route of exposure to enteric viruses is by direct contact with infected persons or by contact with faecally contaminated objects.

However, because of the ability of viruses to survive and because of the low infective dose, exposure and consequent infections may occur by less obvious means, including ingestion of contaminated water. Explosive outbreaks of viral hepatitis and gastroenteritis resulting from sewage contamination of water supplies have been well documented epidemiologically. In contrast, the transmission of low levels of virus through drinking water of potable quality, although suspected of contributing to the maintenance of endemic enteric viral disease within communities, has not yet been demonstrated. In some developing areas, water sources may be heavily polluted and the water-treatment processes may be less sophisticated and reliable. Because of these factors, as well as the large number of persons at risk, drinking water must be regarded as having a very significant potential as a vehicle for the environmental transmission of enteric viruses. As with other microbial infections, enteric viruses may also be transmitted by contaminated food. Enteric viruses are capable of producing a wide variety of syndromes, including rashes, fever, gastroenteritis, myocarditis, meningitis, respiratory disease and hepatitis. In general, asymptomatic infections are common and the more serious manifestations rare. However, when drinking water is contaminated with sewage, two diseases may occur in epidemic proportions – gastroenteritis and infectious hepatitis. Apart from these infections, there is little, if any, epidemiological evidence to show that adequately treated drinking water is concerned in the transmission of virus infections. Gastroenteritis of viral origin may be associated with a variety of agents. Many of these have been identified only recently occurring as small particles with a diameter of 270–350 microns in stools of infected individuals with diarrhoea. Viral gastroenteritis, usually of 24–72 hours' duration with nausea, vomiting and diarrhoea, occurs in susceptible individuals of all ages. It is most serious in the very young or very old where dehydration and electrolyte imbalance can occur rapidly and threaten life if not corrected without delay. Hepatitis, if mild, may require only rest and restricted activities for a week or two, but when severe it may cause death from liver

failure, or may result in chronic disease of the liver. Severe hepatitis is tolerated less well with increasing age and the fatality rate increases sharply beyond middle age. The mortality rate is higher among those with pre-existing malignancy and cirrhosis.

12.2.3.3 Protozoa

Protozoa are single-celled eucaryotic micro-organisms without cell walls. The majority of protozoa are aerobic. Protozoa feed on bacteria and other microscopic micro-organisms. Of the intestinal protozoa pathogenic for humans, three may be transmitted by drinking water: *Entamoeba histolytica, Giardia* spp. and *Balantidium coli*. These organisms are the etiological agents of amoebic dysentery, giardiasis and balantidiasis, respectively, and have all been associated with drinking water outbreaks. All three have worldwide distribution. As a group, the intestinal pathogenic protozoa occur in large numbers in the faeces of infected individuals in humans and a wide variety of domestic and wild animals. Coliform organisms do not appear to be a good indicator for *Giardia or E. histolytica* in treated water because of the increased resistance of these protozoans to inactivation by disinfection.

12.2.3.4 Helminths

A great variety of helminth eggs and larvae have been detected in drinking water and it is clear that all those infective to humans should be absent if the water supply is to be safe. However, the majority of helminths are not water-borne and it is neither feasible nor necessary to monitor water for them on a routine basis. Two groups of helminths are more directly related to water supplies:

- those transmitted wholly by the ingestion of infected copepod intermediate hosts; and
- those whose cercariae are directly infective to humans. A third category groups the remainder of the species.

The first group (*Dracunculus, Spirometra*) comprises helminths that develop in aquatic copepods and are acquired by humans ingesting water containing the intermediate host crustacea. The most important member in this group is the guinea-worm (*Dracunculus medinensis*), a filarial parasite of humans. Tapeworms of the genus *Spirometra*, though much rarer in humans, also have a stage in aquatic copepods. Adult worms are found in the small intestine of cats. Eggs pass out in the faeces and hatch in water where they may be ingested by copepods.

The second group (*Schistosoma, Ancylostoma, Necator*) comprises a miscellaneous group of flukes and roundworms whose infective larvae are able to penetrate the human skin and mucous membranes. The human hookworms *Ancylostoma duodenale* and *Necator americanus*, both with a wide tropical and subtropical distribution, have eggs that hatch and develop in the soil to the third stage larvae, which then reinfect humans by penetrating the skin. Hookworms of domestic animals may also invade humans.

The third group of helminths has resistant eggs or cysts infective to humans. If these gain access to drinking water and are ingested, humans become infected. The most widespread intestinal helminths are *Ascaris lumbricoides* (roundworm) and *Trichuris trichuria* (whipworm). The human tapeworms of the genera *Hymenolepis*, with a direct life cycle, and *Echinococcus*, where humans are infected by ingesting eggs usually acquired from dogs, have the potential for spread in drinking water.

12.2.3.5 Malaria and dengue

Both malaria and dengue are not transmitted directly by drinking water but by vectors or carriers that breed in water, in this case mosquitoes. In order to prevent the spread of these diseases, it is of the utmost importance that in all endemic areas, drinking water

reservoirs within the port area be adequately covered to prevent mosquitoes from gaining access to the free water surface. These reservoirs comprise:

- elevated water distribution tanks (access manholes);
- reinforced concrete reservoirs (access manholes);
- header tanks, whatever size; and
- water cisterns in all toilets.

All manholes should be covered with purpose-made manhole covers and all vents should be equipped with mosquito-net filters. Furthermore, all horizontal areas should be laid to falls to prevent the rainwater forming ponds and adequate drains installed to handle runoff. These areas include roofs, parking areas, access ways and derelict land within the port's boundaries.

12.2.4 Nutrients

Nitrates and nitrites are considered together because conversion from one form to another occurs in the environment. The health effects of nitrates are generally a consequence of its ready conversion to nitrite in the body. Nitrates are widely present in substantial quantities in soil, in most waters and in plants, including vegetables. Nitrites also occur fairly widely, but generally at very much lower levels than nitrates. Nitrates are products of oxidation of organic nitrogen by the bacteria present in soils and in water where sufficient oxygen is present. Nitrites are formed by incomplete bacterial oxidation of organic nitrogen. One of the principal uses of nitrate is as fertilizer. Nitrates are also used in explosives, as oxidizing agents in the chemical industry and as food preservatives. Its occurrence in water is brought about by fertilizer use, decaying vegetable and animal matter, sewage effluents, industrial discharges, leachates from refuse dumps.

Nitrates in the water are limited to 10 ppm.

12.2.5 PRIORITY POLLUTANTS

12.2.5.1 Introduction

These are organic or inorganic compounds selected on the basis of their known or suspected carcinogenicity, mutagenicity, teratogenicity or high acute toxicity.

12.2.5.2 Arsenic

Arsenic is notorious as a toxic element. Its toxicity, however, depends on the chemical (valency) and physical form of the compound, the route by which it enters the body, the dose and duration of exposure and several other biological parameters. It is recommended that, when water is found to contain arsenic at levels of 0.05 ppm, an attempt should be made to ascertain the valency and chemical forms of the element. Arsenic is commonly associated as an alloying additive with lead solder, lead shot, battery grids, cable sheaths and boiler piping. Nowadays, most arsenic originates from paints or pharmaceuticals and is commonly found in sewage. The concentration of arsenic in seawater is around 0.002 ppm. The primary concerns are carcinogenicity and mutagenicity.

12.2.5.3 Asbestos

Asbestos is a general term for fibrous silicate minerals of the amphibole and serpentine mineral groups. Six minerals have been characterized as asbestos: chrysotile, crocidolite, anthophyllite, tremolite, actinolite and amosite. Asbestos is commonly found in domestic water supplies. The use of asbestos-cement (170 grams of asbestos per kilograms – 80 percent chrysotile and 20 percent crocidolite) for pipes in distribution

systems could contribute to the asbestos content of drinking water. Background levels are reported to be in the range of less than 1 million to 10 million fibres per litre. The primary concern is carcinogenicity. Use of asbestos is now banned.

12.2.5.4 Barium

Barium is present in the earth's crust in a concentration of 0.50 g/kg and the mineral barytes, barium sulphate, is the commonest source. Traces of barium are present in most soils.

Barium is also present in traces in many foodstuffs, such as brazil nuts. Barium is also used in various industrial processes, such as in vacuum tubes, spark-plug alloys, Getter alloys, Fray's metal and as a lubricant for anode rotors in X-ray machines. Drinking water should not contain more 0.050 ppm.

12.2.5.5 Beryllium

Beryllium is commonly found as part of feldspar mineral deposits and may exist as the mineral beryl in small localized deposits. The primary source of beryllium in the environment is the burning of fossil fuels, although contamination is normally light. Beryllium can enter the water system through weathering of rocks in ground aquifers, atmospheric fallout on rain water collection systems and industrial and municipal discharges. Beryllium is used in metal alloys and certain electrical components. Not all countries have set standards for limits of beryllium in drinking water. Those that have limit its presence to 0.20 ppb.

12.2.5.6 Selenium

As a result of geochemical differences, levels of selenium in soil and vegetation vary within broad limits. The chemical form of selenium, and thus its solubility, is another decisive factor as regards its presence in drinking water. Selenium has been identified as an essential nutrient in several animal species, including humans. Dietary selenium levels of 5 mg/kg of food or more may cause chronic intoxication, and in seleniferous areas this value has been considered as the dividing line between toxic and non-toxic feeds. Drinking water in general does not represent the only or main source of selenium exposure for the resident population in seleniferous areas. There is a range of selenium intake by humans that is consistent with health, and outside this range deficiency or toxicity can occur. Selenium in drinking water is limited to 0.01 ppm.

Selenium is widely used in the electronics industry, television cameras, solar batteries, computer cores, rectifiers, xerographic plates and ceramics as a colorant for glass. It is also used as a trace element for animal feeds.

12.2.5.7 Silver

Silver occurs naturally in elemental form and as various ores. It is also associated with lead, copper and zinc ores. Because some metals such as lead and zinc are used in distribution systems and also because in some countries silver oxide is used to disinfect water supplies, silver levels in tap water may sometimes be elevated. The levels of silver in drinking water should not exceed 1 ppb.

In industry, silver is used in the manufacture of silver nitrate, silver bromide and other photographic chemicals, water distillation equipment, mirrors, silver plating equipment, special batteries, table cutlery, jewellery, and dental, medical and scientific equipment including amalgams.

12.2.6 REFRACTORY ORGANICS

12.2.6.1 Introduction

This group of contaminants is wide ranging and consists of chlorinated alkanes (carbon tetrachloride), chlorinated ethenes (polyvinyl chloride, or PVC), polynuclear aromatic hydrocarbons (naphtalene, coal tar), pesticides, herbicides and fumigants (DDT, endrin, aldrin, lindane, methoxychlor, toxaphene and silvex), mono-dichlorobenzenes (solvents), benzenes (benzene, toluene), phenols and chlorophenols and trihalomethanes (chloroform, bromoform).

12.2.6.2 Chlorinated alkanes

One of the major uses of chlorinated alkanes in the chemical industry is as an intermediate in the production of other organochlorine compounds. They are therefore produced in large quantities and consequently many are found in raw and finished drinking water. Carbon tetrachloride is a haloalkane with a wide range of industrial and chemical applications. It has been found to be an occasional contaminant of chlorine used in the disinfection of drinking water but is not produced in drinking water as a result of the chlorination process itself. Carbon tetrachloride was extensively used as a propellant for aerosols. This chemical has been found to be a carcinogen to laboratory animals. The guideline limit of this chemical is 3 ppb.

12.2.6.3 Chlorinated ethenes

This group of compounds is used widely in a variety of industrial processes as solvents, softeners, paint thinners, dry-cleaning fluids, intermediates, etc. Because of their wide use, they are often found in raw and treated drinking water. Because of their high volatility, they are usually lost to the atmosphere from surface water and therefore generally occur at lower concentrations. Vinyl chloride is mainly used for the production of PVC resins which, in turn, form the most widely used plastics in the world. Low concentrations of PVC have been detected in effluents discharged by chemical and latex manufacturing plants and in drinking water as a result of leaching from substandard (improperly cured) PVC pipes used in water distribution systems. Vinyl chloride is associated with cancer and is mutagenic in a number of biological systems, including *Salmonella* and *E. coli*. Other chlorinated ethenes include 1,1-dichloroethene (used in the packaging industry), trichloroethene (used as a dry-cleaning solvent) and tetrachloroethene (used in dry-cleaning and as a degreasing agent in metal industries). The guideline limit for PVC is 20 ppb.

12.2.6.4 Polynuclear aromatic hydrocarbons

Polynuclear aromatic hydrocarbons (PAHs) are a large group of organic compounds present in the environment from both natural and industrial sources. PAHs are rarely encountered singly in the environment and many interactions can occur with mixtures of PAHs whereby the potency of the known carcinogenic PAH may be enhanced. These systems are not well understood, however, and their significance as regards environmental exposure to PAH is not yet clear. Contact with coal-tar based linings during distribution is known in some instances to lead to an increase in PAH concentration in water. Because of the close association of PAH with suspended solids, the application of treatment to achieve an acceptable level of turbidity will ensure that minimum PAH levels are achieved. Aromatic hydrocarbons may enter the aquatic environment of the harbour basin from discharges from vessels as ballast water, bilge pumping, engine exhaust, effluents from coastal refineries, crude oil power stations, terrestrial runoff (particularly from urban storm water containing road asphalt particles) and leaching (creosoted components from jetties and wharves). A guideline of 0.01 ppb is recommended.

12.2.6.5 Pesticides

Pesticides that may be of importance to water quality include chlorinated hydrocarbons and their derivatives, persistent herbicides, soil insecticides, pesticides that are easily leached out from the soil, and pesticides systematically added to water supplies to control disease vectors, such as mosquito larvae (malaria and dengue fever).

Of these compounds, only the chlorinated hydrocarbon insecticides occur frequently and these are very persistent in the environment where they have become ubiquitous. Typical pesticides include:

- *Dichlorodiphenyltrichloroethane (DDT)*: a persistent insecticide, stable under most environmental conditions and resistant to complete breakdown by enzymes present in the soil micro-organisms.
- *Aldrin and dieldrin*: two related and very persistent pesticides which accumulate in the food chain. Currently may be used for termite control around the roots of fruit trees.
- *Chlordane*: a broad-spectrum insecticide also used for termite control and for homes and gardens.
- *HCB or hexachlorobenzene*: produced commercially for use as a fungicide.
- *Heptachlor*: another broad-spectrum insecticide used to control agricultural soil insects. Heptachlor is very persistent.
- *Lindane*: a wide-spectrum insecticide of the group called organochlorine insecticides and used in a wide range of applications, including treatment of animals, buildings, water (for mosquitoes), plants, seeds and soil.
- *Methoxychlor*: an insecticide used for the treatment of agricultural crops and livestock. Guidelines for refractory organics limit total "*drins*" to 0.03 ppb and total "*ddt*" to 1.0 ppb.
- *Mono-dichlorobenzenes*: monochlorobenzene is widely used as a solvent and in the manufacture of several chemicals, such as insecticides and phenols. Dichlorobenzenes are important intermediates for dyes, moth repellants, deodorants, dielectric fluids, heat transfer fluids and insecticides.
- *Benzenes*: benzene and toluene are produced mainly from petroleum or as a by-product in the manufacture of gas. Both chemicals are widely used in the chemical industry both as intermediates and for the production of styrene, phenol, acetone and cyclohexane (used in manufacturing nylon). Significant quantities of toluene are used in the manufacture of plastics, paints, detergents and as petrol additives. The guideline for benzene in water is 10 ppb.
- *Phenols and chlorphenols*: chlorphenols are used as biocides and are found in water as a result of chlorinating water supplies containing phenol. Chlorphenols are well known for their low taste and odour thresholds. For aesthetic reasons therefore individual phenols should not, as a general rule, be present in drinking water above 0.1 ppb. The best approach to controlling pollution by chlorphenols is to prevent the contamination of the source water by phenol (from petrochemical industries) and chlorinated phenolic pesticides (agriculture).
- *Trihalomethanes*: trihalomethanes (chloroform and bromoform) in drinking water occur principally as products of reaction of chemicals used in oxidative treatment reacting with naturally occurring materials present in the water. Their formation is particularly associated with the use of chlorine for disinfecting water supplies. Notwithstanding this, it is important to recognize the fact that chlorine is an effective water disinfectant and the hazards of disease arising from microbiological contaminants resulting from incomplete disinfection are substantial. Trihalomethanes have several adverse effects on health and the guideline value limits chloroform in drinking water to 30 ppb.

12.2.7 DISSOLVED INORGANICS

12.2.7.1 Introduction

Dissolved inorganic compounds are generally associated with the aesthetic and organoleptic (taste and odour) characteristics of drinking water. For health-related contaminants, what is unsafe for one is unsafe for all, while aesthetic and organoleptic characteristics are subject to social, economic and cultural considerations.

Since the majority of consumer complaints regarding water quality relate to its colour, taste or odour, the quality of drinking water, as perceived by the senses, largely determines the acceptability of a particular water.

12.2.7.2 Aluminium

Aluminium does not appear to be an essential nutrient to humans. Compared to the aluminium intake from food, that from water is small. The incidence of discoloration in drinking water in distribution systems increases if the aluminium level exceeds 0.1 ppm.

12.2.7.3 Chlorides

Chlorides are widely distributed in nature and are present in mineral deposits, in seawater and some industrial processes. The taste threshold for chloride in drinking water is dependent upon the associated cation, but is usually within the range of 200 to 300 ppm of chloride. Based on organoleptic considerations, the guideline value for chloride is 250 ppm.

12.2.7.4 Colour

Colour in drinking water may be due to the presence of coloured organic substances, such as humics (decay of vegetation in the water); metals such as iron and manganese; or highly coloured industrial wastes, of which pulp, paper and textile wastes are the most common. Chlorine from the chlorination process is likely to give rise to high levels of trihalomethanes due to the reaction of chlorine with dissolved humic substances.

12.2.8 Heavy metals

12.2.8.1 Introduction

Trace quantities of many metals are important constituents of most waters. Many of these metals are also classified as pollutants. The presence of any of these metals in excessive quantities will interfere with many beneficial uses of the water because of their toxicity.

12.2.8.2 Cadmium

Cadmium is widely distributed in the Earth's crust but is particularly associated with zinc and copper and is produced commercially only as a by-product of zinc smelting. Cadmium shows no signs of being an essential trace element in biological processes; on the contrary, it is highly toxic to the human organism. Like mercury, cadmium and its compounds only enter the environment from geological or human activities (metal mining, smelting and fossil fuel combustion).

Cadmium and its compounds are blacklisted materials, which by international agreement may not be discharged or dumped into the environment. Cadmium is a cumulative poison and a maximum level of 0.005 ppm is permitted for drinking water.

12.2.8.3 Chromium

Most rocks and soils contain small amounts of chromium. Chromium in its naturally occurring state is in a highly insoluble form; however, most of the more common soluble forms found in soils are mainly the result of contamination by industrial emissions.

The major uses of chromium are for chrome alloys, chrome plating, oxidizing agents, corrosion inhibitors, pigments for the textile glass and ceramic industries as well as in photography. Hexavalent chromium compounds (soluble) are carcinogenic and the guideline value is 0.05 ppm.

12.2.8.4 Lead

Lead is not only the most abundant of heavy metals occurring in nature, it was also one of the first metals used on a large scale by humans. Although it is not a nutritionally essential element, its monitoring is important because of its toxicity to human health. Lead is a cumulative poison. Most of the lead produced in metallic form, in batteries, cable sheathing, sheets and pipes, etc., is recovered and recycled, but most lead used in compound form, such as paints and petrol additives, is lost to the environment, eventually ending up in the aquatic environment. Lead compounds, similar to the ones used in petrol additives are reportedly being used in the production of mercurial fungicides. The presence of lead in drinking water is limited to 0.01 ppm.

12.2.8.5 Mercury

Although a comparatively rare element, mercury is ubiquitous in the environment, the result of natural geological activity and human-induced pollution. Mercury from natural sources can enter the aquatic environment via weathering, dissolution and biological processes. Although extremely useful to humans, mercury is also highly toxic to the human organism, especially in the form of methyl mercury, because it cannot be excreted and therefore acts as a cumulative poison. The potential for long-term human health hazards from ingesting mercury-contaminated fish has led several nations to establish regulations and guidelines for allowable seafood mercury levels. Nearly all levels above 1 ppb in water are due to industrial effluents connected with chlorine and caustic soda production, pharmaceuticals, mirror coatings, mercury lamps and certain fungicides.

12.2.8.6 Nickel

Nickel is ubiquitous in the environment. Nickel is almost certainly essential for animal nutrition and, consequently, it is probably essential to humans. Nickel is a relatively non-toxic element; however, certain nickel compounds have been shown to be carcinogenic in animal experiments.

12.2.8.7 Tin

Tin and its compounds are significant and controversial chemicals in the environment. As is the case with other elements, not all chemical forms of tin are equally biologically active. In contrast to the low toxicity of inorganic tin (derived from eating canned foods), some organic tin compounds, also known as organotins, are toxic. Tributyltin and triphenyltin, constituents of anti-fouling paints, are highly toxic and their presence in harbour waters is limited to generally 0.002 and 0.008 ppb respectively.

A new International Maritime Organization Convention prohibits the use of harmful organotins in anti-fouling paints used on ships and will establish a mechanism to prevent the potential future use of other harmful substances in anti-fouling systems. The International Convention on the Control of Harmful Anti-fouling Systems on Ships was adopted on 5 October 2001. However, in many countries, organotin anti-fouling paints are still available from old stocks and the start of the fishing season generally sees an increase of this compound in the water as freshly painted vessels are launched back into the water.

12.2.8.8 Copper

The presence of copper in the water supply, although not constituting a hazard to health, may interfere with the intended domestic uses of water. Copper enhances corrosion of aluminium and zinc fittings, stains clothes and plumbing fixtures. Copper is used in alloys, as a catalyst, in anti-fouling paints and as a wood preservative. Urban sewage contains substantial amounts of copper. The human taste threshold for copper is low, 5.0–7.0 ppm, and the taste is repulsive. The limit for drinking water is 1.0 ppm.

12.2.8.9 Iron

The presence of iron in drinking water is objectionable for a number of reasons unrelated to health. Under the pH conditions existing in drinking water supplies, ferrous salts are unstable and precipitate as insoluble ferric hydroxide, which settles out as rusty silt. Such water tastes unpalatable, promotes the growth of "iron bacteria", and the silt gradually reduces the flow of water in the piping. The recommended guideline level of iron in water is 0.3 ppm.

12.2.8.10 Manganese

Anaerobic groundwater often contains elevated levels of dissolved manganese. The presence of manganese in drinking water is objectionable for a number of reasons unrelated to health. At concentrations exceeding 0.15 ppm manganese imparts an undesirable taste to beverages and stains plumbing fixtures. The recommended value is 0.1 ppm.

12.2.8.11 Sodium

The sodium ion is ubiquitous in water owing to the high solubility of its salts and the abundance of mineral deposits. Near coastal areas, wind-borne sea spray can make an important contribution, either by fallout on to land surfaces where it drains to the water source or from washout by rain. Domestic, commercial and industrial discharges are another source of sodium in water. In general, sodium salts are not acutely toxic substances because of the efficiency with which mature kidneys excrete sodium. The effects on infants, in contrast to adults, are different because of the immaturity of infant kidneys. A maximum of 200 ppm is allowed in drinking water.

12.2.8.12 Zinc

The concentration of zinc in tap water can be considerably higher than that in surface water owing to the leaching action of zinc from galvanized pipes, brass and other zinc alloys. Zinc imparts to water an undesirable astringent taste and in concentrations in excess of 5 ppm water may appear opalescent and develop a greasy film on boiling. Levels of zinc should be kept well below this value.

12.2.8.13 Petroleum hydrocarbons

Humans have a very low taste threshold for petroleum hydrocarbons and the taste is particularly repulsive. All components of crude oil are degradable by bacteria, though at varying rates, and a variety of yeasts and fungi can also metabolize petroleum hydrocarbons. Water-soluble components of crude oils and refined products include a variety of compounds that are toxic. High-molecular-weight tars are less damaging in the water than medium-molecular-weight compounds such as diesel. Low-molecular-weight compounds are generally unimportant because they are very volatile and rapidly evaporate. Therefore, a diesel spillage at sea is more damaging than crude oil (very tarry) or petrol spillage. For harbour basin water, the limit for dissolved hydrocarbons should not exceed 0.30 ppm. Polluted harbour water can impart an unpleasant flavour to fish if used for washing. Commercial fishermen may also risk tainting a whole catch if their nets have been fouled by diesel or oil.

12.2.8.14 Sulphates

Sulphates are widely distributed in nature and excessive amounts of dissolved sulphates in drinking water lead to problems with hardness. Taste threshold concentration for the most prevalent sulphate salts are: 200 to 500 ppm for sodium sulphate; 250 to 900 ppm for calcium sulphate; and 400 to 600 ppm for magnesium sulphate. In drinking water, dissolved sulphates are limited to 400 ppm.

12.2.8.15 Hardness

Water hardness is the traditional measure of the capacity of water to react with soap, hard water requiring a considerable amount of soap to produce lather. The degree of hardness of drinking water has been classified in terms of its equivalent $CaCO_3$ concentration as follows:

Soft	0–60 ppm
Medium hard	60–120 ppm
Hard	120–180 ppm
Very hard	180 and above

Soft water has a greater tendency to cause corrosion of pipes and, consequently, certain heavy metals such as copper, zinc, lead and cadmium may be present in the water.

Very hard water, on the other hand, can cause considerable incrustations in pipes and fittings, especially in fish processing plants.

12.2.8.16 pH

The value of the pH, expressed as a value ranging between 1 and 10, is a good indicator of the state of the water. Values of 9.5 and above are alkaline in taste. Values of 3 and below are acidic in taste. Values lower than 6 cause problems with corrosion. Values below 4 support little life in a marine environment. Drinking water should have a pH in the range 6.5 to 8.5. Harbour water should have a pH of between 6 and 9.

12.2.8.17 Hydrogen sulphide

Hydrogen sulphide occurs as a by-product in septic tanks when proteins in sewage are attacked by certain bacteria. Traces in excess of 0.05 ppm cause taste and odour problems.

12.3 MONITORING

Depending on the actual state of the fishing harbour infrastructure and the environmental conditions obtaining in and around the harbour itself, monitoring tests for contaminants should be carried out according to a specific programme. Unless local sanitary standards are rigidly enforced, typical monitoring programmes should reflect local environmental conditions.

12.3.1 Boreholes

Potable water supplies based on borehole extraction are very susceptible to contamination by sewage, pesticides and salt water intrusion. Contamination may also arise from pollutants entering the water table some distance from the port or from sewage entering the borehole itself in the port area through cracked or corroded casings. In cases where overdrawing is evident (water is brackish), bacterial tests should be run very frequently, say once a week; otherwise, every month. Complete tests should be run every six months.

12.3.2 Municipal mains

It is not uncommon for municipal or mains water supply to be contaminated at source (through malfunctioning or inoperative chlorination equipment) or for the supply to pick up contaminants through corroded sections of a pipeline leading to the fishing harbour. Complete tests should be run every six months and the relevant authorities informed of the results.

12.3.3 Water towers and reservoirs

Both types of structure are susceptible to bacterial growth if the residual chlorine levels in them are low or non-existent. Testing may not be necessary if periodic scrubbing is carried out. If the water tower cannot be decommissioned for maintenance, then bacteria tests should be carried out every six months or so.

12.3.4 Harbour basin water

Typically, harbour basins should be tested once a year. However, in areas where monsoons are very active, it may be advisable to test at the peak of the dry season (when effluent point discharges tend to remain concentrated in the water course) and then again during the wet season (when agricultural runoff may find its way into the water course). Another critical period for harbours is the peak of the fishing season (when most of the fleet is up and running and fuel and oil are discharged from the bilges).

12.3.5 International water standards

The tables given in Appendix 1 and 2 to this chapter illustrate standard water quality parameters for both potable water (World Health Organization) and harbour basin waters (European Union Directives). If harbour basin water is being used for rinsing fish, then it too must satisfy drinking water standards for contaminants.

12.4 PERSONAL HYGIENE AND PORT SANITATION

The standard of personal hygiene of the workers employed inside a fishing harbour depends on both the sanitary infrastructure available and the harbour management in enforcing certain directives. The sanitary infrastructure is made up of:

- toilet facilities (with adequate showers);
- adequate supplies of soap and detergents; and
- appropriate signs and billboards displayed at strategic places.

In general, the sanitary infrastructure should be able to cater for the total number of potential workers within the harbour boundary; this is especially so for harbours with high seasonal landings, where for a period of one to three months in the year the increase in the number of workers may swamp the facilities meant for a low-season workforce.

12.4.1 Sanitary fittings

Toilets should be constructed to the highest standards possible to ensure the maximum lifetime. Poorly built facilities break down very quickly and generally lead to "toilets of opportunity" elsewhere around the port. Toilet facilities should always be properly maintained and full-time manning by attendants is desirable. Toilets should never open on to a work area where fish is being handled due to the risk of flooding from blocked drains. The standard of personal hygiene of the workers employed inside the fishing port depends on the quality of the facilities provided.

In many developing countries, the major reason for breakdown is not vandalism but incorrect design and specification of the fittings at the design stage, followed by a total lack of supervision during construction and poor operational management and

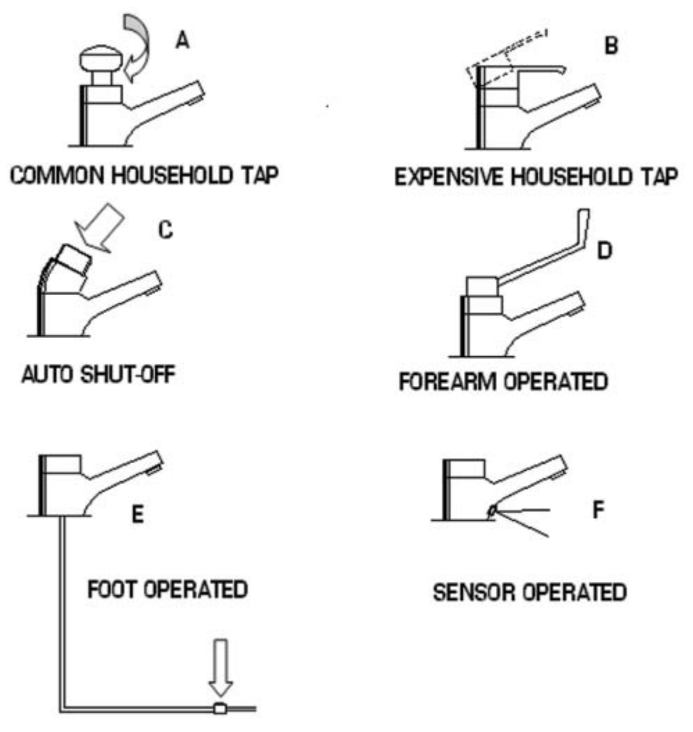
maintenance. The three most common fittings likely to break down prematurely under current design practices are:

- water taps;
- toilet flush systems; and
- shower heads.

It is not uncommon to enter a public toilet facility inside a fishing port and notice that water taps are either inoperable or missing altogether. In all probability, the taps specified would have been the most economical variety of the common household tap. Figure 1 shows the most common types of water taps available on the market today, ranging from the very economical household variety to the more sophisticated sensor operated type. For the fitting to satisfy health hygiene regulations it may not be of the types shown in Figures 1A and 1B because reclosing the tap by hand may retransfer bacteria on to a clean hand. In addition to this, the household taps often specified are not designed for the wear and tear of a public facility. In most public places such as airports, train stations and restaurants, the water taps are of the self-closing type shown in Figures 1C, 1E and 1F. The forearm operated type shown in Figure 1D, typically seen at the doctor's or dentist's clinic, is also suitable and may be more economical than the other types. However, the industry standard is the foot-operated unit as illustrated in Figure 2.

Shower units (shower head and tap) are also problematic, especially if slightly saline or calcium-rich borehole water is in use. Most household shower heads corrode easily as do most wall-mounted valve or tap handles. To ensure a longer lasting unit, all pipes, heads and valves should be in PVC or HDPE plastic. Valves should be of the ball type with few moving parts. Pipework should not be embedded in the walls but fixed externally with appropriate anchor fixings. The internal cubicles of showers should be glazed. Mortar finishes are not suitable for a damp environment.

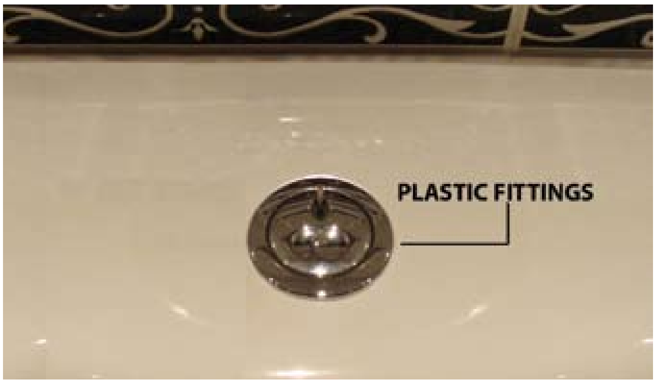
FIGURE 1
Typical types of water taps available



Many types of toilet flush systems are available on the market, but as with the other types of sanitary fittings household varieties are not suitable for repeated use in a public facility. Most household cisterns are very fragile and often break down for the most minor of things (Figure 3).

FIGURE 2
Correct type of water tap recommended

FIGURE 3
Household-type cistern with fragile plastic fittings



12.4.2 Buildings

The building should be simple in layout, airy, brightly coloured and with plenty of ventilation (Figure 4). All the floor drains inside the building should be bar drains placed centrally across the room with water draining away from the walls to prevent flooding (Figure 5). The drains should be in plastic and easily removed to clear blockages.

All toilet facilities should be equipped with lighting to enable use during night-time unloading and auctioning operations. Toilet facilities should be attended, especially in artisanal harbours where the facility may also serve the village residents.

Steel piping in sanitary facilities is gradually being replaced with PVC or HDPE (high-density polyethylene) piping. The obvious advantages over steel are resistance to corrosion and ease of installation and maintenance. However, when installing external pipework, care must be taken to employ a material that is ultraviolet stabilized. Ultraviolet rays from the sun attack certain plastics and the proper material should be specified for all external pipework.

FIGURE 4
Optimal layout of small toilet facility

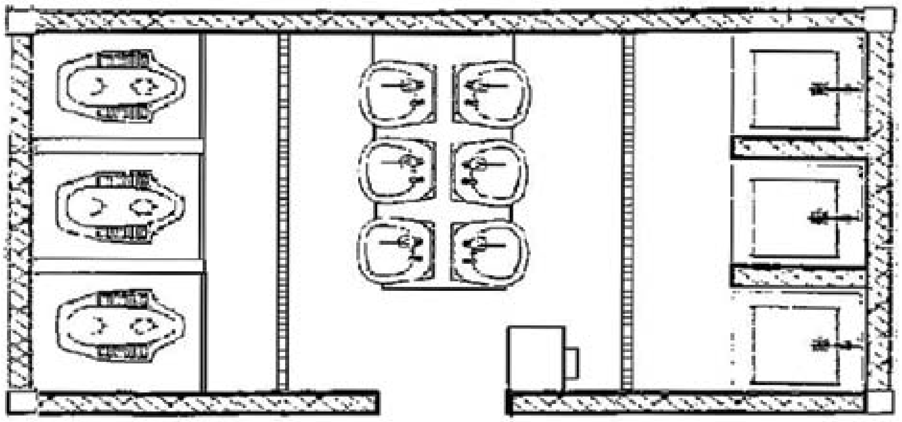
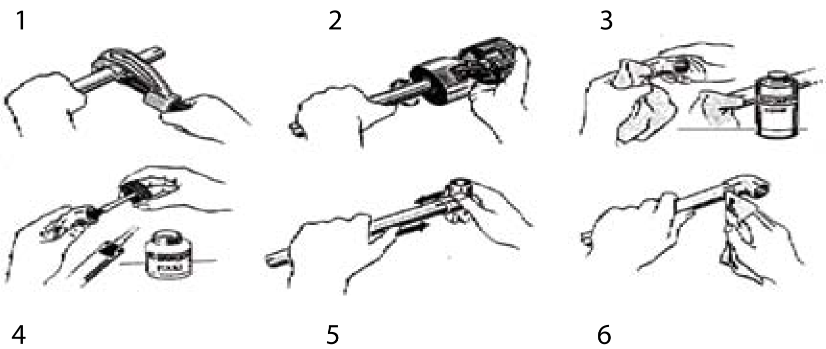


FIGURE 5
Required standard of finish for toilet facilities

Two methods of jointing plastic pipe are available: heat welding or glue. Heat welding involves heating the pipe ends by a small heater similar to a hairdryer and then applying force to weld the seams together. Gluing, however, is now the accepted industry standard because it involves little capital equipment, apart from the glue, Figure 6.

FIGURE 6
Gluing an elbow joint



1. Cutting, 2. Reaming, 3. Cleaning, 4. Application of glue, 5. Fixing, 6. Wiping joint clean

Similarly, repairing a leaking elbow joint or length of pipe is also very quick and needs no special tools, Figure 7.

The traditional bronze or brass gate valves are also being gradually replaced with ball valves, Figure 8. Ball valves are made from resistant plastic with a stainless steel ball valve. They have fewer moving parts and no corrodible fittings.

FIGURE 7
Repairs to a PVC pipe are simple

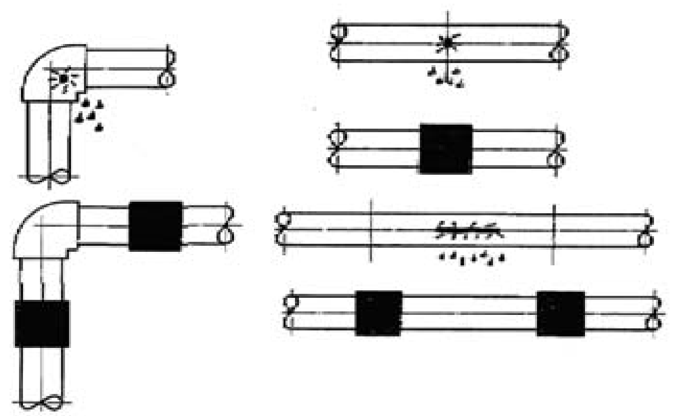
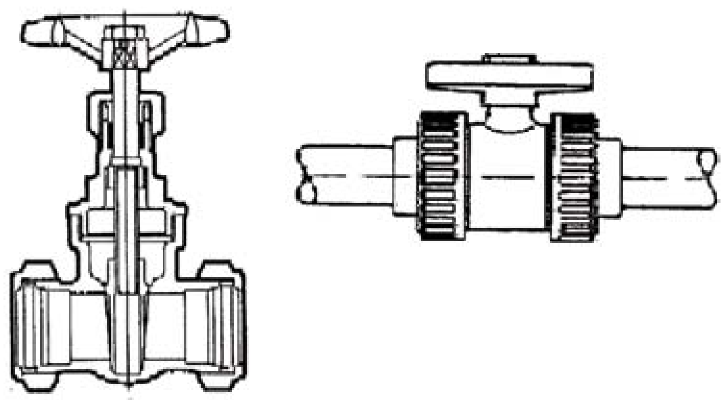


FIGURE 8
Gate valves (left) and ball valves (right))



12.4.3 Signs and billboards

Port sanitation is to the port what personal hygiene is to the workers employed by the port. Appropriate signs and billboards listing food hygiene regulations should form part of the harbour's sanitary awareness infrastructure. These signs should be displayed at all the strategic locations within the port boundary, for example:

- "*NO SMOKING, NO SPITTING, NO EATING*" signs should be posted wherever fish is being handled;
- "*HAVE YOU WASHED YOUR HANDS*?" signs should be posted at all toilet exits.

Adequate signs should also be posted in prominent locations indicating the direction to the toilets. Proper and frequent training of the port workers in personal hygiene should form part of the harbour master's management brief.

Port sanitation is best explained by the following simple regulations:

- All water supplies inside the port boundary should comply with the World Health Organization drinking water standards or national drinking water standards where these are higher.
- All ice, including that brought in from outside suppliers, should also comply with the above drinking water standards.
- All chlorination equipment should be functional and adequate supplies of the chlorination agent should be held in stock.
- All sampling and testing carried out inside the port should be carried out by ISO certified laboratories only.
- Appropriate signs should be displayed within the port area covering, among other things, dumping, spillage, use of seawater from inside harbour basin, spitting, eating areas, prohibited access to domestic animals, etc.
- Appropriate billboards should be displayed at strategic locations listing fines for the contravention of port hygiene rules.
- All drainage systems (indoor and outdoor) should be kept in perfect working order.
- Port perimeter fences should be properly maintained to keep unauthorized people and domestic animals from entering the port area at any time.
- The entrance and exit to a fishing port area should be manned during business hours to prevent unauthorized people from gaining entry to the fish handling areas.
- Disinfection of required areas should be carried out on a regular basis.
- No excessive trash and wet wastes should be left to accumulate in work areas.
- No rodent harbourage should exist in and around the port area (tall weeds, junk piles and municipal rubbish).
- No birds should be nesting inside open-sided auction halls and fish handling sheds.
- Only employees and officially recognized fish traders should be allowed access to work areas during fish handling operations and auctions.
- Toilet and shower facilities should be kept scrupulously clean and in perfect working order.
- Only electrically powered machinery should be allowed inside the auction or handling sheds to prevent oil, petrol and diesel from leaking onto the floors which are sometimes used as auction surfaces for large fish.
- The entire fish handling area should be hosed down properly at the end of business and locked up to prevent unauthorized entry until the next auction.

12.5 SEWAGE TREATMENT

The sewage effluent or wastewater from a fisheries harbour typically consists of three major biologically degradable constituents:

- **Type 1** – effluent from the toilets, faecal matter in water (typically low-volume discharge);
- **Type 2** – effluent from the wash hand basins and showers, soapy water (detergents present, also low-volume discharge); and
- **Type 3** – effluent from the fish cleaning operations, fish blood, scales and fish solids, high-volume discharge.

The combined effluent from a fishing harbour should ideally be connected to a municipal sewer to be taken away and treated with normal household sewage. If such a sewer is not available within a reasonably economic distance, then the effluent has to be treated before being discharged into a watercourse. Depending on the size of the

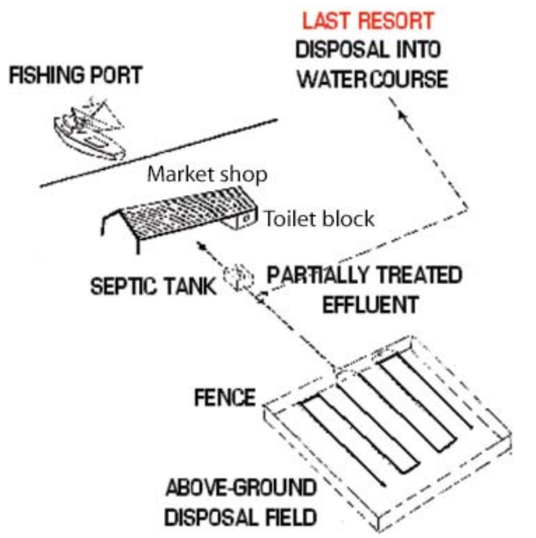
fishing harbour, the effluent may be treated either via septic tanks and on-site natural treatment systems (artisanal harbours only) or via a proper sewage treatment plant (coastal, offshore and distant-water harbours). In both cases, adequate space should be provided for the purpose.

12.5.1 Type 1 effluent – artisanal harbours

Artisanal harbours are more often than not situated in areas where basic municipal infrastructure is very primitive or even totally absent; introduction of sophisticated mechanical wastewater effluent treatment systems may also not be a viable option due to the costs involved. Natural treatment systems, on the other hand, may be designed to take advantage of the physical, chemical and biological processes that occur when water, soil, plants, micro-organisms and the atmosphere interact. The processes involved in natural systems include many of those used in sophisticated mechanical treatment systems, such as sedimentation, filtration, gas transfer, adsorption, ion exchange, chemical precipitation, chemical oxidation, and biological conversion and degradation – plus others unique to natural systems such as photosynthesis, photo-oxidation and plant uptake. In natural systems, the treatment process occurs at natural rates and tends to occur simultaneously in a single ecosystem reactor. In a mechanical system, the processes occur sequentially in separate tanks at accelerated rates as a result of energy input. Figure 9 provides a typical solution for artisanal fishing harbours.

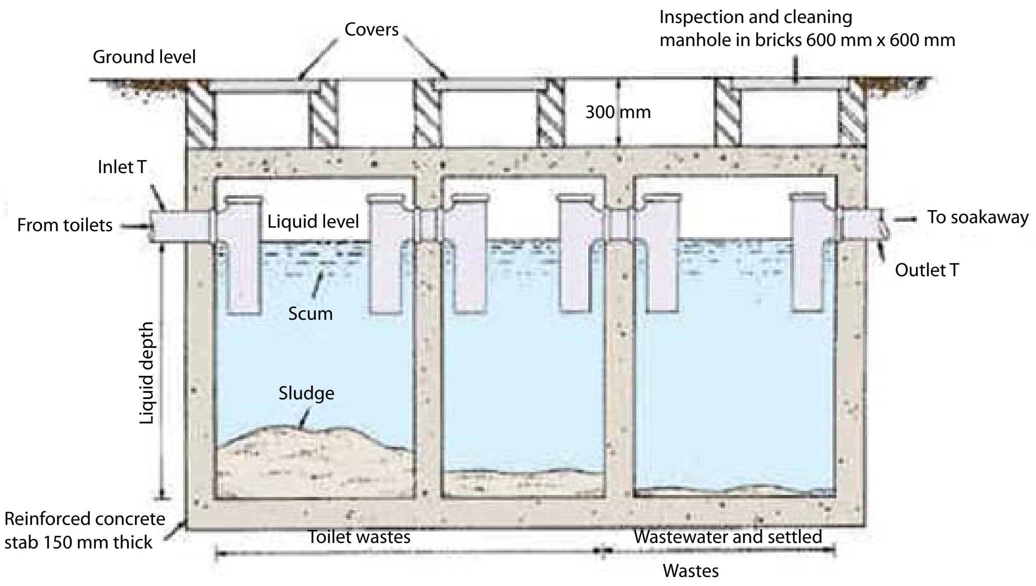
The first stage of a natural treatment system is the septic tank, Figure 10, generally located in or around the harbour and into which all the effluent should be directed. A three-stage septic tank is a rectangular underground chamber divided internally into three compartments. After coarse screening through a basket sump, the effluent is retained inside the compartments for a minimum period of three days; during this period, the solids in suspension settle to the bottom of the first compartment where they are attacked and digested by bacteria. As a result, the volume of sludge is greatly reduced and the effluent clarified to some extent. Appropriate manholes should be provided over each compartment to enable sludge to be removed (pumped out) during maintenance.

FIGURE 9
Typical solution for an artisanal fishing port



The dimensions of the chamber should be such that peak total daily effluent flows are retained for a minimum period of three days inside the tank. Obviously, the larger the volume to be treated, the larger the tank should be. Various methods are available to reduce the volume of water to be treated, such as high-pressure jet cleaners for hosing down operations (largest consumer of water), automatic or spring-loaded taps over wash-hand basins and dual-flush action toilet flushing equipment.

FIGURE 10
Typical three-stage septic tank



The following guidelines may be used when calculating a harbour's total daily effluent flow rate.

Auction hall flow rate

- 1 litre per kilogram of fish landed every day;
- 10 litres per square metre of covered area (reduced to 2.5 litres if a high pressure jet cleaner is used); and
- 10 litres per fish box handled (reduced to 2.5 litres if a high pressure jet cleaner is used).

Toilet and shower facilities flow rate

- 100 litres per person per day (full-time employees + part-time handlers and sellers + crew in port).

Canteen services (hot food cooked on premises) flow rate

- 15 litres per serving per day.

The total volume should be adjusted for peak summer landing conditions when fish handling and visiting crews are at their peak numbers.

The effluent from the septic tank should then be piped for further treatment to one of several types of natural treatment systems and only discharged into a waterway or into the sea as a last resort. Natural treatment systems may consist of one of the following:

- Slow rate treatment (effluent is sprayed or channelled over vegetated land to provide treatment), Figure 11.
- Constructed wetlands – emergent plants (effluent is fed into inundated areas that support growth of emergent plants such as cattail, bulrush, reeds or sedges), Figure 12.
- Constructed wetlands – floating aquatic plants (effluent is fed into inundated areas that support plants of the floating species such as water hyacinth and duckweed), Figure 13.
- Rapid infiltration (effluent is applied intermittently to shallow spreading basins and lost into the ground), Figure 14.

Slow rate treatment, the predominant natural treatment process in use today, involves the application of effluent or wastewater to vegetated land to provide treatment and to meet the growth needs of the vegetation, Figure 11. The applied water is either consumed through evapotranspiration or percolates vertically and horizontally through the soil profile. Any runoff is usually collected and reapplied to the system. This system needs moderately slow soil permeability and in areas of high precipitation needs effluent storage. The effluent may be applied via sprinklers or furrows. Typical area requirements for this system are 15 to 45 acres per million litres of effluent per day.

Two types of constructed wetland systems have been developed for wastewater treatment: free water surface flow systems and subsurface flow systems, Figure 12.

FIGURE 11
Typical above-ground slow rate treatment field

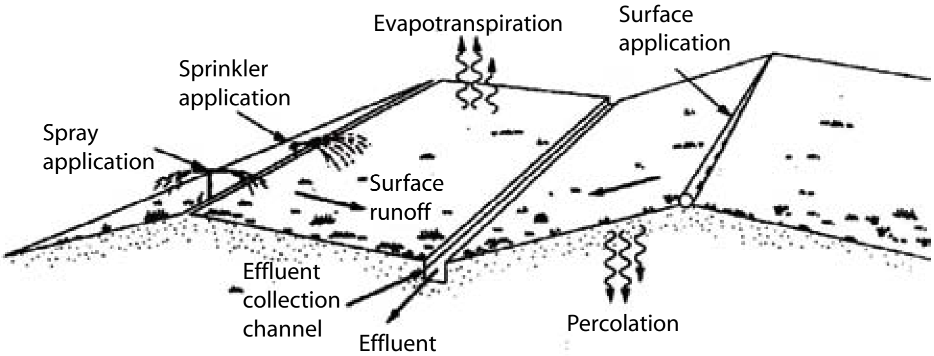
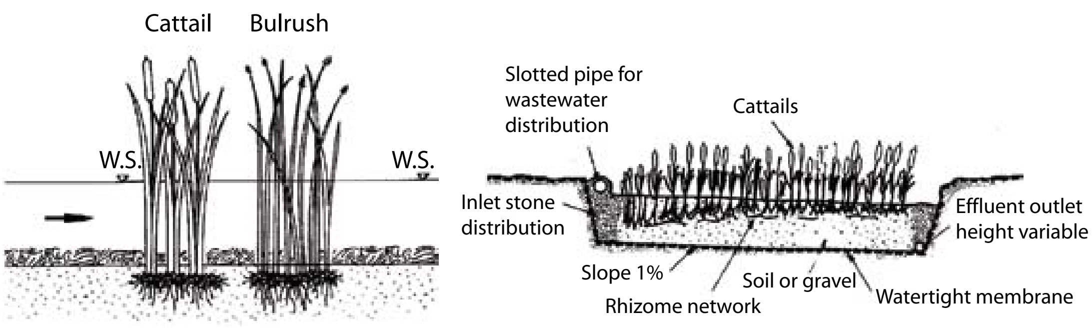


FIGURE 12
Subsurface water flow (right) and free water surface flow (left)

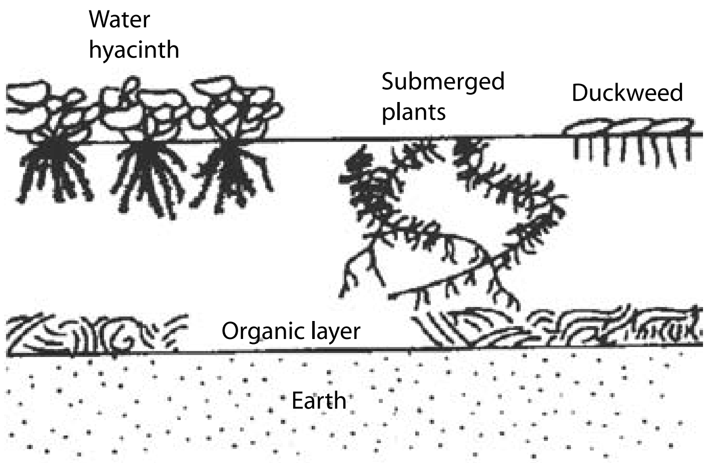


The water depth in this system is typically very shallow, ranging from 0.10 to 0.60 metres. Subsurface flow systems are designed with an objective of secondary or advanced levels of treatment. These systems have also been called root zone or rock reed filters and consist of channels or trenches with relatively impermeable bottoms filled with sand or rock media to support emergent vegetation.

This system is generally classified as a constructed wetland where the effluent may be collected after treatment and reutilized in agriculture. Lack of a free water surface in the subsurface flow system also makes it ideal for areas prone to mosquito infestation. Effluent storage is needed in areas of high precipitation and, typically, 4 to 14 acres per million litres of effluent treated daily are required.

Constructed wetlands offer all of the treatment capabilities of natural wetlands but without the constraints associated with discharging to a natural ecosystem. Floating aquatic plant systems are similar in concept to free water surface systems except that the plants are floating species such as water hyacinth and duckweed. Water depths are typically deeper, ranging from 0.50 to 1.80 metres, Figure 13.

FIGURE 13
Wetland with floating aquatic plants



Supplementary aeration has been used with floating plant systems to increase treatment capacity and to maintain aerobic conditions necessary for the biological control of mosquitoes. For this reason, the ponds should be stocked with mosquito fish. Area requirements are similar to other wetland systems.

In rapid infiltration systems, wastewater effluent is applied on an intermittent schedule usually to shallow infiltration trenches or spreading basins. Vegetation is not usually provided. The evaporative losses in this system are only a small fraction of the applied water and, hence, most of the applied effluent percolates through the soil profile where treatment occurs. The treatment potential of rapid infiltration systems is somewhat less than that for slow rate systems because of the lower retention capacity of the soil and relatively higher inflow of water. In coastal areas, where the groundwater level is high or the underlying strata not permeable enough, pressure-dosed field trenches have been successfully used, Figure 14. Pressure distribution, which serves to distribute the effluent evenly over the sand in the trench, is a key factor contributing to the success of this type of disposal.

FIGURE 14
Sand-filled trench

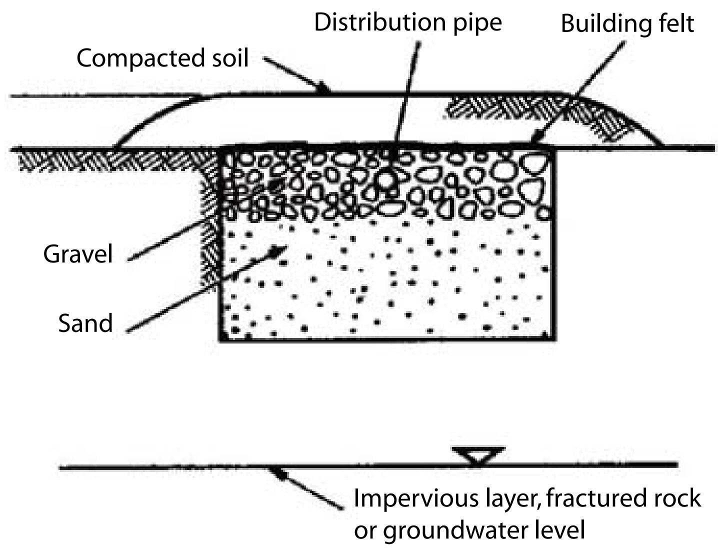
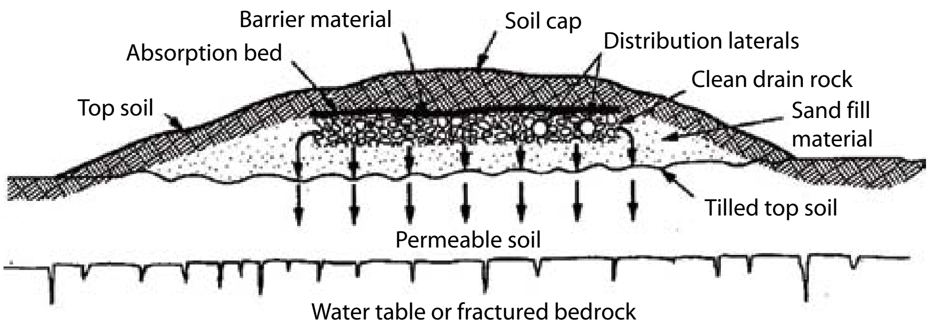


FIGURE 15
Mound system



The mound system, Figure 15, is essentially an intermittent sand filter that is placed above the natural surface of the ground. The effluent in this system is pumped from the septic tank through a piped pressure distribution system placed at the apex of the gravel layer. Mound systems have been used in areas where the soils are permeable and the water table very high or the soils not permeable at all. The system works well only if the water accumulated under the mound can be pumped away. This system requires mechanical pumping at all stages of the treatment and may not be suitable in areas which lack a steady power supply.

Which system is the most suitable?

This question cannot be answered until the site has been evaluated. The principal considerations in the design of a natural wastewater treatment system are:

- a preliminary site assessment;
- detailed site evaluation; and
- assessment of the hydraulic assimilation capacity of the terrain.

The preliminary site assessment should consider the geomorphological features of the area, such as surface slopes, existing marshes or wetlands, flooding potential, groundwater extraction, water-table levels and landscaping.

The detailed site evaluation should include identification of the soil characteristics, percolation coefficients and hydrogeological characterization of the area.

From these investigations it should be possible to determine the hydraulic assimilation capacity of the area, i.e. the suitability of the area to receive septic tank effluent without jeopardizing the environment and public health.

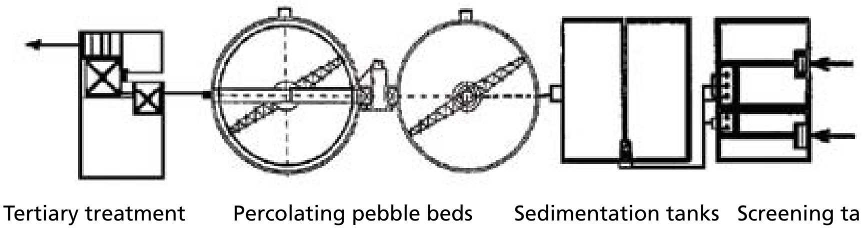
Freshwater should be utilized in the toilet flushing system when septic tanks are used for treating wastewater. The presence of seawater (up to 30 percent) in the raw effluent decreases the efficiency of the bacterial decomposition of the sludge. Beyond 50 percent of seawater, bacterial decomposition is seriously compromised.

12.5.2 Type 1 effluent – other ports

Other harbour installations situated away from municipal centres should install proper sewage treatment plants which can handle a larger volume of water and produce an effluent which may be discharged directly into a watercourse. Depending on the required degree of purity of the effluent, a sewage treatment plant (Figure 16) may consist of:

- screening and disintegration (removal of major solids);
- sedimentation (to settle out organic solids into sludge);
- biological filtration (over a pebble bed inside circular tanks); and
- tertiary treatment such as micro-straining, aeration and upward flow rapid gravity sand filters.

FIGURE 16
Typical modern sewage treatment plant



In small plants, screening for large solid matter which may interfere with pipe flow is generally carried out with manually racked bar screens at 60° to the flow.

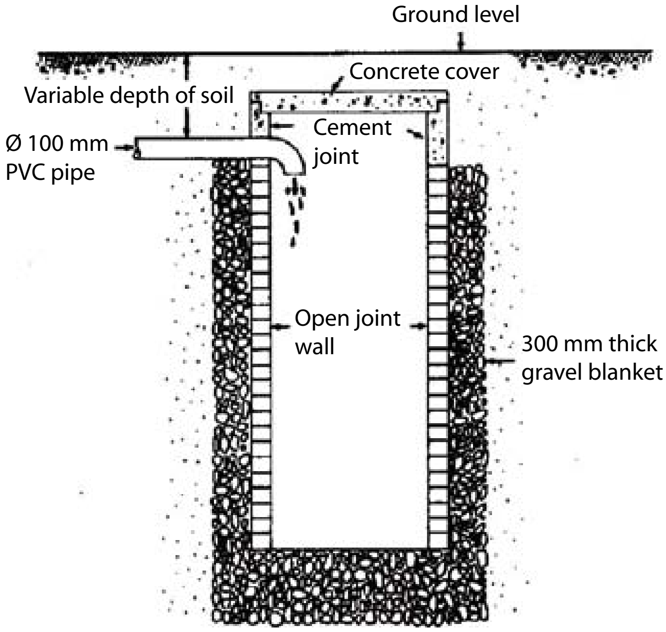
The rest of the organic solids are then macerated by means of a special pump and the fluid pumped into long sedimentation tanks; there, the drop in velocity allows some of the suspended matter to settle as sludge which is then removed periodically, dried and disposed of (buried, burned or dumped offshore). The biological treatment is achieved by spraying the liquid from the sedimentation tanks over a pebble bed by slow-moving rotating arms. Here, biological oxidation takes place (aerobic digestion) by micro-organisms in the slime covering the stone pebbles. If further treatment is necessary, the fluid is then pumped into a tertiary treatment section; otherwise, the liquid is pumped to an outfall which should be located a distance away from the harbour.

12.5.3 Type 2 effluent – wash-hand basins

In artisanal ports, where the sewage is treated through a septic tank, the effluent containing detergents from the wash-hand basins and the shower units may be discharged into a soakaway away from the septic tank or to a constructed wetland (Figure 17).

Although soakaways have the potential to drastically reduce the volume of sewage to be treated, they are only suitable for sandy terrain and their location must be such that it does not contaminate drinking water borewells.

FIGURE 17
The soakaway



12.5.4 Type 3 effluent – market floor runoff

Market, auction and processing floors are generally hosed down using copious amounts of water; the water may contain both solids (fish scales, discards, entrails, etc.) and liquids (blood and fish oils). This runoff is not a health hazard in itself but rather a nuisance; it may indirectly attract pests to the food handling area, such as flies. Before entering the drainage system, this runoff should be channelled to a basket drain to separate all the solids which may otherwise cause blockages in the drainage system. The basket drain should be in stainless steel or plastic and easily accessible for cleaning. Moreover, due to the large volume of water involved, this runoff should preferably never be mixed with the toilets effluent as this will appreciably increase the flow rate through the septic tank. This runoff water is best diverted to a soakaway, and if clean seawater is used for this purpose, then an adequate outfall should be installed to channel it directly back into the sea.

In larger installations it may still be uneconomical to channel this large volume of runoff to the treatment plant as this will increase the basic cost of treatment for all effluent. If environmental conditions permit (absence of sharks, outfall placed outside the harbour basin, strong currents present near shore, etc.), this runoff may also be channelled directly into the sea via a long underwater outfall.

An alternative solution to the dilemma of the increased volume of water is to reduce drastically the volume of runoff at source, i.e. at the handling halls and this may be achieved by the use of high-pressure cleaning equipment.

Small compact high-pressure cleaners manage to clean a surface using about one fifth to one fourth of the volume of water normally used by a common 20 mm diameter hose. The potential savings in water consumption may outweigh the cost of the electric power (3 to 5 Kw) required to operate the cleaners, Figures 18 and 19. Most cleaners come equipped with a small container to inject disinfectant (bleach) into the water jet, a useful requirement for washing and sterilizing fish boxes simultaneously.

FIGURE 18
A typical mobile high-pressure cleaner for use in auction hall

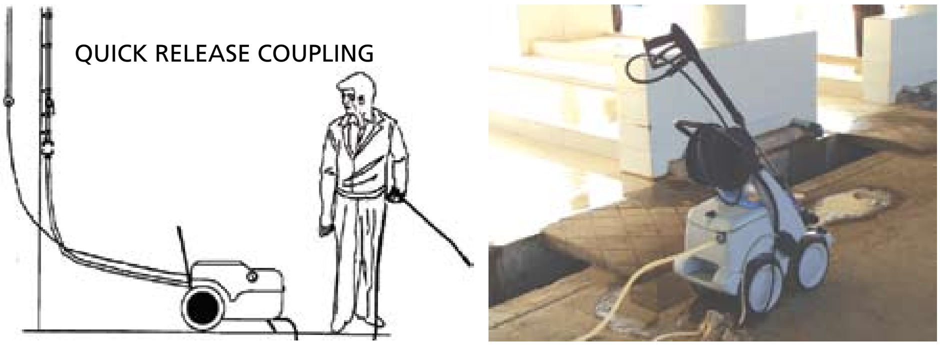
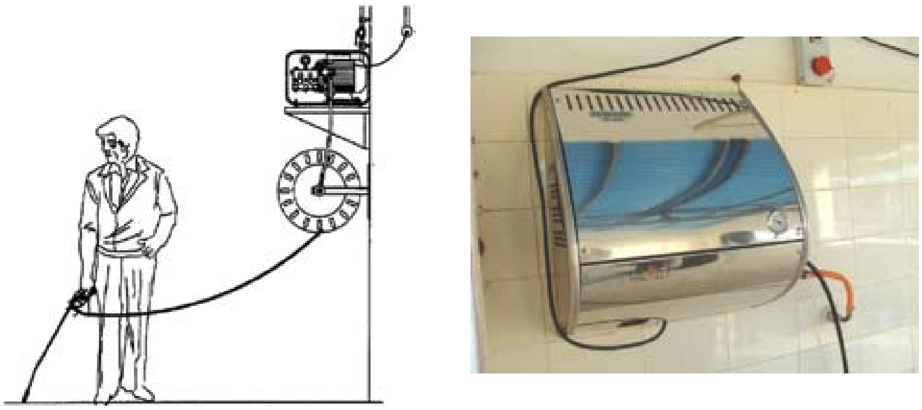


FIGURE 19
A typical wall-mounted high-pressure cleaner for fish box washing



12.6 PORT WASTES[2]

Apart from sewage, a port's waste stream consists of five different types of wastes which may be broadly classified as toxic and non-toxic. The toxic wastes are:

- batteries;
- spent engine oil and bilge water oil; and
- contaminated spares and consumables.

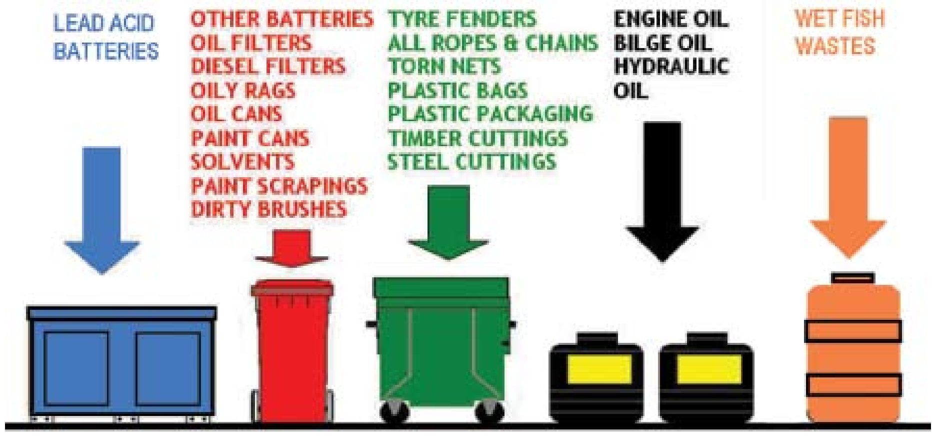
The non-toxic wastes are:

- plastic consumables and dunnage, including nets; and
- wet fish wastes.

Figure 20 indicates the layout and colour coding used in most countries to distinguish between the different waste streams.

[2] The port planner should keep abreast of debates at the IMO Committee on Flag State Implementation with regard to facilities to be provided by port States.

FIGURE 20
A fishing port's waste stream



12.6.1 Batteries

Rechargeable lead-acid batteries contain plates of lead immersed in sulphuric acid inside a plastic case. Lead-acid batteries are recyclable and most suppliers take spent batteries back for industrial reprocessing. Sunlight may decompose the plastic casing, so proper on-site storage of spent batteries is required to prevent the highly toxic contents from spilling out (Figure 21).

FIGURE 21
Abandoned battery with split casing (left) and the recommended battery on-site storage container (right)

12.6.2 Spent oil

Oily wastes discharged to reception facilities are usually mixtures of oil, water and, in some cases, solids. The composition ratio of these solids can differ considerably, depending on the type of wastes. Waste oil and fuel residues consist mainly of oil contaminated with water, whereas bilge water consists mainly of water contaminated with oil. Waste oil may be 100 percent recycled and in many countries it is now mandatory to collect used oil from different sources for recycling. Reception facilities for used engine oil inside harbours, Figures 22 and 23, are intended as a temporary storage only, whereas the reception facilities for bilge water need to separate the oil from the considerably larger volume of water. This oil can then be transferred to the used oil storage facilities for collection at a later date and the treated water returned back to the sea.

FIGURE 22
Used oil drums may be converted to spent-oil storage in artisanal ports

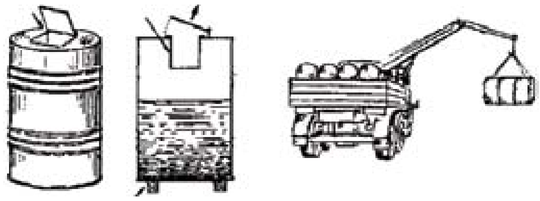
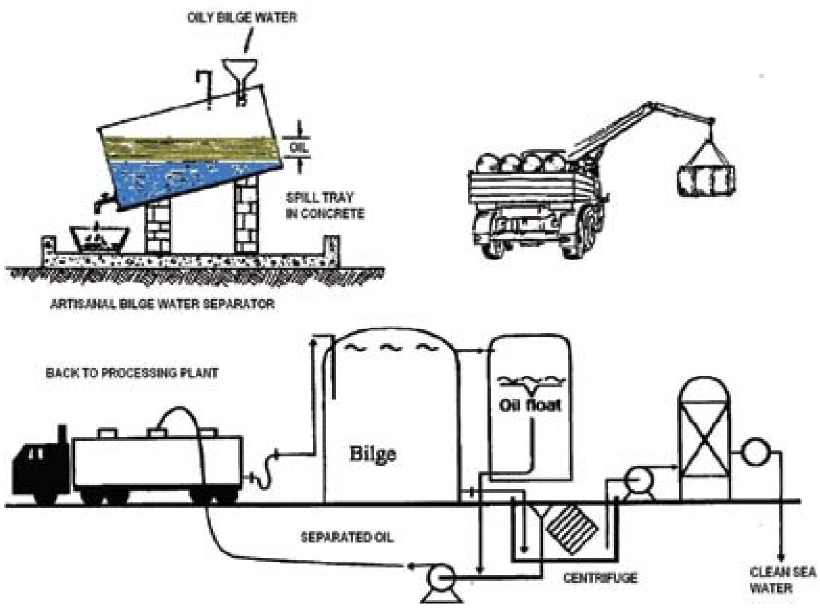


FIGURE 23
Artisanal storage (left) and modern storage equipment (right)

12.6.3 Bilge water separation

Oily bilge water is normally found on inboard motorized fishing vessels and consists of engine oil (leaked out from the engine) mixed with seawater (leaked into the vessel from various sources including around the propeller shaft of many vessels), and if left standing still long enough, the oil fraction separates from the seawater and coalesces on the surface. Bilge water should not be dumped overboard but collected at the port for separation and eventual recycling of the oil fraction. The separated seawater may be returned to the sea. Both artisanal and commercial separators are available, Figure 24. Many of the larger fishing vessels are equipped with oily water separators;

FIGURE 24
Oily bilge water separators



the oil being returned to a holding tank and the water pumped overboard. If the oil (often a mixture of lubricating oil and fuel oil) cannot be clarified and purified on board (for further use) it has to be discharged ashore when in port for treatment. Figure 25 shows a modern vertical oil coalescer.

FIGURE 25
Modern vertical oil coalescer in plastic (no moving parts)

12.6.4 Solid waste bins

Non-toxic solid waste comprises all kinds of bulky items such as old tyre fenders, pieces of rope and netting, broken fish boxes, etc. The equipment for handling this waste should facilitate the reception, segregation and temporary storage. Part of this waste may be recycled. However, the actual processing should not take place inside the port. Disposal of this waste may be handled by municipal waste services.

Toxic solid waste comprises normal batteries, oil filters, engine spares, oil and paint cans, solvents, oily rags, etc. None of this waste is normally recycled and this waste is not normally handled by municipal services. This waste must not be sent to a municipal landfill but must be disposed of in a hazardous waste landfill.

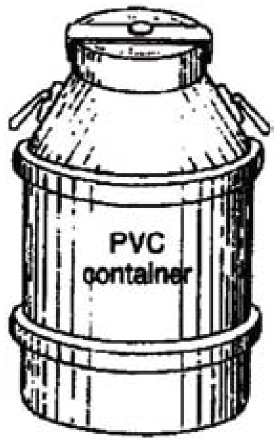
The receptacle capacity should match the demand, both in terms of size and number of receptacles that are required and space availability. Small receptacles such as barrels or oil drums are not suitable for bulky items. Household garbage from neighbourhood communities should not be dumped inside the port facilities. In practice, it may be found that both open top and closed containers are needed, especially in areas where wind is very strong and where common garbage is generated inside the port and cannot be stored in open top skips due to the presence of pests (cats and dogs) (see Figure 26).

FIGURE 26
Solid waste bins

12.6.5 Wet waste bins

In theory, fish should be cleaned and gutted on board the fishing vessels on their journey back to port and dumped out at sea where it provides food for other fish. In practice, however, much cleaning and gutting still goes on inside harbours and it is well worth installing reception facilities for the collection and eventual disposal of wet wastes. Irrespective of the size of the harbour, the best receptacle to use is an airtight PVC drum (Figure 27).

FIGURE 27
Air-tight PVC container



These airtight containers should be placed at vantage points all round the fish handling areas. They should be placed in cool sheltered spots away from direct sunlight to avoid rapid decomposition of the fish. The disposal methods for wet wastes are various and all appear to produce the desired result, i.e. removal of wastes which may attract pests or vermin. The following methods are practiced in various countries:

- burial of limited quantities to produce fertilizer;
- reloading on designated vessels for offshore dumping (a minor fee is levied on the landings to pay for this service); and
- privatizing the service via a concessionary agreement with an animal feed cottage industry.

12.6.6 Flotsam collection and disposal

Whether a fishing port is located inside a river mouth or on an open coastline, flotsam inevitably finds its way into the harbour area. This floating debris may consist of:

- natural flotsam such as branches, logs, seaweed, etc.; and
- rubbish caused by humans including fishing netting, wet fish wastes, carcasses of domestic animals, household plastic litter and spilt oil.

Besides being a hazard to navigation, some of this material may also be a hazard to public health (raw harbour water may be in use for rinsing fish) and should be removed. Depending on the particular site conditions, the flotsam should be gathered and disposed of in the proper manner. Figure 28 illustrates a vessel designed to scoop up flotsam.

FIGURE 28
Self-propelled flotsam scooper

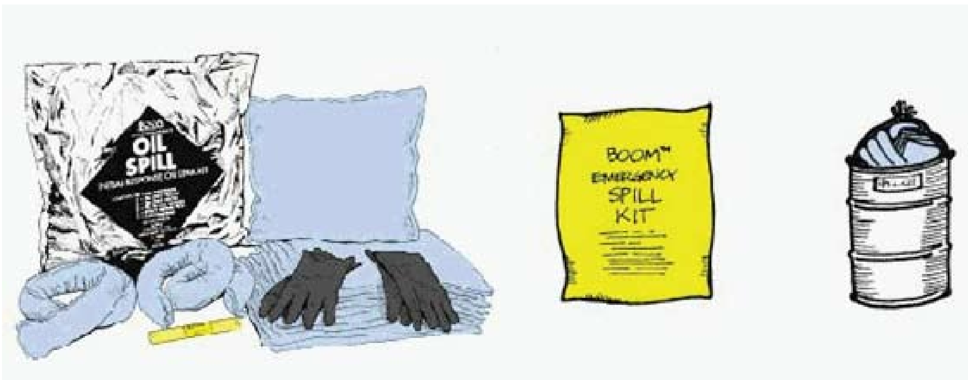
Figure 29 illustrates how two fishing vessels trawling in tandem (pair trawling) can scoop flotsam over a wide area. The net, suitably buoyed with plastic floats, is towed across by two fishing vessels proceeding at a low steady speed. The flotsam in the net may then be brought ashore for sorting and disposal.

FIGURE 29
Tandem trawling for flotsam by two vessels

12.6.7 Fuel and oil spill response

Diesel fuel may leak into the harbour basin through careless handling during the refuelling operations and engine oil may be pumped out during the emptying of the bilges. All fishing ports should be equipped with a standard oil spill response package consisting of disposable oil spill booms and absorbent pads, disposal bags, latex gloves and plastic barrels for the sealed disposal of the oil-soaked disposable items (Figure 30). The port management staff should be instructed in the proper handling of fuel and trained in emergency oil-spill management.

FIGURE 30
Disposable oil-spill response equipment



12.7 PEST CONTROL

In many developing countries it is not uncommon to see domestic animals wandering about the fishing port or landing site. Some animals, such as goats and poultry, are sometimes purposely kept whereas dogs and cats move in to mop up scraps of food left lying around. It is also very common for rodents and houseflies to invade such

places, especially when fish is part-processed (dried) inside the port area. Birds also find shelter and ideal roosting places among the roof trusses of the old-fashioned type sheds. Table 2 presents the best practice options for pest control.

TABLE 2
Best practice options for pest control

Type of nuisance	Type of issue	Best practice option
Rodents	Infrastructure-Management	Provide receptacles for wet wastes and enforce housekeeping
Flies	Infrastructure-Management	Provide net-covered hangars and enforce use
Birds nesting inside fish-handling shed	Infrastructure	Install netting or false ceilings under trussed roofs. New roofs should be of a flat slab design or trussless
Cows, dogs, goats and cats	Infrastructure	Install fence and controlled access

12.7.1 Rodents

The best method to keep rodents at bay is strict housekeeping. Wet-waste bins, as illustrated in Figure 27, should be made available all round the port area and all fish wastes disposed of properly. Strict housekeeping rules must be enacted and enforced. All unwanted fish carcasses (Figure 31) must be removed immediately and haphazard use of the port area for slaughtering large fish should be forbidden.

FIGURE 31
Abandoned fish carcasses and uncontrolled processing inside port area

12.7.2 Flies

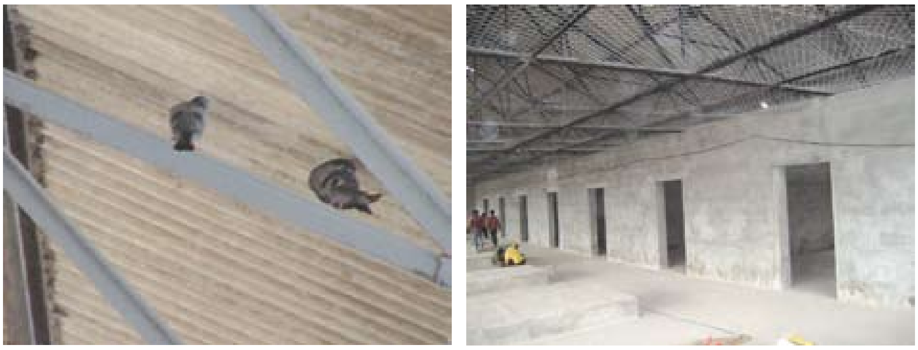
Fish drying in the open air invites flies to lay eggs in the exposed flesh rendering the finished product unhygienic. Fish drying should take place under a netted steel or aluminium structure as illustrated in Figure 32. These structures are commonly used in fish farming.

FIGURE 32
Net-covered metal framework suitable for fish drying or smoking

12.7.3 Birds

All port structures with open trussed roofs offer birds ample opportunities for roosting and building nests. Bird droppings on the working surfaces below present a hygiene hazard, especially if the fish is exposed during sorting or icing. All such structures should be made bird proof by installing wire or plastic netting on all the undersides and ensuring that all the roofing panels are intact (Figure 33).

FIGURE 33
Pigeons nesting on a truss (left) and a bird-proofed truss (right)



12.7.4 Domestic animals

Domestic animals should not knowingly be kept inside port and fish landing areas and fresh meat markets should not be allowed within the port or landing area. The major requirements for controlling domestic animals around a port are illustrated in detail in Chapter 11 and consist of:

- controlled main entry gate;
- cattle grid; and
- perimeter boundary wall.

The boundary wall should not take the form of a fence as this is easily breached to create shortcuts. The first metre of wall off the ground should be solid masonry and this may be topped by a steel or wire fence as illustrated in Figure 53 in Chapter 11.

12.8 BIBLIOGRAPHY AND FURTHER READING

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APPENDIX 1

WORLD HEALTH ORGANIZATION
MAXIMUM ALLOWABLE LIMITS FOR DRINKING WATER STANDARDS

PARAMETER	UNIT	LIMIT
Aluminium	mg Al/l	0.2
Arsenic	mg As/l	0.05
Barium	mg Ba/l	0.05
Berylium	ug Be/l	0.2
Cadmium	ug Cd/l	5.0
Calcium	mg Ca/l	200.0
Chromium	mg Cr/l	0.05
Copper	mg Cu/l	1.0
Iron total	mg Fe/l	0.3
Lead	mg Pb/l	0.01
Magnesium	mg Mg/l	150.0
Manganese	mg Mn/l	0.1
Mercury	ug Hg/l	1.0
Selenium	mg Se/l	0.01
Sodium	mg Na/l	200.0
Zinc	mg Zn/l	5.0
Chlorides	mg Cl/l	250.0
Cyanide	mg Cn/l	0.1
Fluorides	mg F/l	1.5
Nitrates	mg NO_3/l	10.0
Nitrites	mg NO_2/l	-
Sulphates	mg SO_4/l	400.0
Suphides	mg H_2S/l	0
TOTAL "drins"	ug/l	0.03
TOTAL "ddt"	ug/l	1.0
Hydrocarbons	mg/l	0.1
Anionic detergents	mg/l	0
pH		6.5 – 8.5
Total dissolved solids	mg/l	500
Total hardness	mg/l	500
Alkalinity	mg/l	500

MICROBIOLOGICAL PARAMETERS

Total bacteria	Count/ml	100
Coliform	Count/100 ml	0
E. Coli	Count/100 ml	0
Salmonella	Count/100 ml	0

ug = microgram

mg = milligram

APPENDIX 2

EUROPEAN UNION DIRECTIVES
SUGGESTED ALLOWABLE LIMITS FOR
ESTUARY AND HARBOUR BASIN WATERS

PARAMETER	UNIT	VALUE
Mercury	ug Hg/l	0.50 (D)
Cadmium	ug Cd/l	5.00 (D)
Arsenic	mg As/l	0.50 (G)
Chromium	mg Cr/l	0.50 (G)
Copper	mg Cu/l	0.50 (G)
Iron	mg Fe/l	3.00 (G)
Lead	mg Pb/l	0.50 (G)
Nickel	mg Ni/l	0.50 (G)
Zinc	mg Zn/l	50.00 (G)
Tributyltin	ug /l	0.002
Triphenyltin	ug /l	0.008
Aldrin	ug /l	0.01
Dieldrin	ug /l	0.01
Endrin	ug /l	0.005
Isodrin	ug /l	0.005
TOTAL "drins"	ug /l	0.03
TOTAL "ddt" all 4 isomers	ug /l	0.025
para-ddt	ug /l	0.01
Hexaclorocyclohexane	ug /l	0.02
Carbon tetrachloride	ug /l	12.0
Pentachlorophenol	ug /l	2.0
Hexachlorobenzene	ug /l	0.03
Hexachlorobutadiene	ug /l	0.10
Chloroform	ug /l	12.0
Ethylenedichloride	ug /l	10.0
Perchloroethylene	ug /l	10.0
Trichlorobenzene	ug /l	0.40
Trichloroethylene	ug /l	10.0
Hydrocarbons	ug /l	300.0 (G)
Phenols	ug /l	50.0
Surfactants	ug /l	300.0 (G)
Dissolved oxygen	% Saturation	80-120 (G)
pH		6 - 9
Sulphide	mg /l	0.04 (S)
MICROBIOLOGICAL PARAMETERS		
Faecal coliforms	per 100 ml	2 000
Total coliforms	per 100 ml	10 000
Salmonella		0
Entero viruses		0

ug = microgram
mg = milligram
D - Dissolved
G-Guideline
S-Suggested