PERFORMANCES OF SELECTED WASTE STABILIZATION PONDS IN KENYA

BY

RICHARD F.K. MUNENE

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To my wife Njeri, my daughter Wangari
and my son Kabia

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SUMMARY

The objective of this study was to assess the performance of selected waste stabilization ponds (W.S.P.)

There are two major types of sewage treatment methods used. These are biological trickling filters and waste stabilization ponds. The goals of waste water treatment is to reduce Biochemical Oxygen Demand (BOD), nutrients and suspended solids so that the effluent from sewage treatment plants does not pollute the receiving water body.

This is particularly so in Europe and North America where nearly everybody has access to piped water and aesthetic qualities are stressed.

In Kenya, where most of the rural population draws water directly from rivers, sewage treatment should reduce pathogenes since the receiving rivers are sources of water to rural communities downstream. Such diseases like cholera, typhoid, dysentry and diarrhoea can be passed through polluted water and this is one of the reasons why removal of pathogenes is stressed.

From the work done during analysis, the author found out that in general W.S.P. received high BOD. Loadings (approximately 550mg/l). This is more than anticipated in the designs 350 mg/l for Dandora (WSP). Proper flow measurements in and out of (WSP) are not available and hence effects of seepage and evaporation could not be evaluated.

The analytical results showed that BOD_5 of unfiltered samples ranged from 75 mg/l to 333 mg/l which is far higher than the recommended 20 mg/l E Coli count of WSP effluent ranged from 1×10^4 E Coli/100ml to 3.7×10^5 E Coli/100ml as compared to recommended 5×10^3 E Coli/100 ml.

Suspended solids values ranged from 20mg/l to 225mg/l and this is higher than 30mg/l which is recommended.

The results show that the selected W.S.P. do not perform as anticipated during design. Basic measurements like pH,temperature, flows in and out of ponds should be taken daily while weekly values of BOD, COD and suspended solids should be obtained. Further research should be undertaken to take into account the temperature dependent organic breakdown rate KT used in the design at the various sites, the effect of evaporation and seepage. Also to be studied is the algae that flows out of WSP and gives the effluent the green colour to establish how much this contributes to the BOD_5 of effluent. Total BOD_5 removal in kg/day from ponds should be established.

General impression is that WSP are easier and cheap to operate to obtain required effluent quality although very little monitoring has been carried out to support this belief. However, work to improve the monitoring of WSP is absolutely essential for arriving at suitable treatment plants for Kenya.

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1. INTRODUCTION

Public Health in Kenya

1.1 Health problems in Urban Areas of Kenya

Urbanization can be defined as an increase in the proportions of a nations population located in urban areas. This implies both the geographical relocation of the population as well as an adjustment in the employment structure of a nation.

In Kenya urbanization is the result of rural urban migration and this poses three major health problems viz: i) housing
ii) water supplies
iii) sewerage and refuse disposal

The long term housing policy of the Kenya Government is that of providing a decent house for every family. In all urban centres (2,000 people upwards) the pressing need is far an increase in the numbers and quality of housing to meet the accelerating demand stimulated by migration. The shortage of housing units available underlies the problems of overcrowding, and shanty developments. This leads to problems of water supply and sanitation that are inherent, which normally follow unplanned construction of dwelling houses without adequate facilities.

Water supplies present problems as cities grow and also as per capita consumptions increases due to better health education, rising standards of living and due to high demands in industries.

The third major problem is sanitation. By 1965 estimates, 49% of African households had water closets and these were generally shared by several households. They ranged (72% Nairobi) and (22% Mombasa). Pit and bucket latrines ranged from (65% Mombasa) to (24% Nairobi) whereas other towns averaged 65%. Recently, Nairobi City Council has converted bucket latrines in estates like Kaloleni, Makadara and Ziwani to water borne lavatories. (Vogel et al 1974)

By 1965 overcrowding in Nairobi was estimated to be 50% for the African household. A third of the city population lived in an authorised housing. Another 20% lived in shanties constructed of very temporally materials like cardboards and polythene. These have risen dramatically to this date.

A housing stock that was taken in May 1972 (Vogel et al 1974) showed that there were 122,187 household units, 47% of which were solid/permanent construction and had water supply and sanitary facilities within or attached to house. 31% were predominantly mud or timber with no sanitary facilities or water supply. Where these services were available they were usually communal and at a distance.

These were found in Mathare Valley (13000), Dagoretti (12000) others 5000, Old Pumwani (3000), Old City (2000), Ruaraka/Kariobangi (1500), Old Kibera (mud houses 800).

Related problems are water supply and sewage /refuse disposal. Presently, water supply and distribution are being greatly improved while sewage and refuse disposal are major problems in Mathare Valley.

1.2 Ways in which water supplies affect health

The relation of personal hygiene to health has been recognized far many years and 'cleanliness is next to Godliness' is very much a nineteenth century maxim. Recently a series of epidemiological studies have shown that the details of access to water determine the incidence of several infective diseases. The supplies of available water greatly influence facilities for disposal of human excreta and these in turn affect the spread of many important diseases. (Feachem et al 1972)

In the tropics such vector-borne diseases as malaria, schistosomiasis and yellow fever are terrible scourges and threats to population. Poverty is serious in the rural areas where most people live and around the edges of cities which are the fastest growing communities.

In these areas most people cannot afford a conventionally good water supply at present and these are the areas most suspectible to such vector-borne diseases.

1.3 Classification of water related infections

There are many different infective diseases which may be affected by changes in water supply. Classification is by the microbe causing them and they can be split into viral, bacterial, protozoae and helminthic diseases. They are affected by the mode of spread and can be grouped into four main categories.

a) Infections spread through water supplies - water borne diseases

b) Disease due to lack of water for personal hygiene - water washed diseases

c) Infections transmitted through aquatic invertebrater - water based diseases

d) Infections spread by insects that depend on water - water related diseases.

Table 1.1 Classification of infective diseases in relation to water supplies

Category	Examples	Relevant water improvements
I Water-borne infections		
(a) Classical	Typhoid, cholera	Microbiological sterility
(b) Non-classical	Infective hepatitis	Microbiological improvement
II Water-washed infections		
(a) Skin and eyes	Scabies, trachoma	Greater volume available
(b) Diarrhoeal diseases	Bacillary dysentery	Greater volume available
III Water-based infections		
(a) Penetrating skin	Schistosomiasis	Protection of user
(b) Ingested	Guinea worm	Protection of source
IV Infections with water-related insect vectors		
(a) Biting near water	Sleeping sickness	Water piped from source
(b) Breeding in water	Yellow fever	Water piped to site of use
V Infections primarily of defective sanitation	Hookworm	Sanitary faecal disposal

Table 1.2 Main infective diseases in relation to water supplies

Category	Disease	Frequency	Severity	Chronicity	Percentage suggested reduction by water improvements
1a	Cholera	+	+++		90
1a	Typhoid	++	+++		80
1a	Leptospirosis	+	++		80
1a	Tularaemia	+	++		40?
1b	Paratyphoid	+	++		40
1b	Infective hepatitis	++	+++	+	10?
1b	Some enteroviruses	++	+		10?
1a, IIb	Bacillary dysentery	++	+++		50
1a, IIb	Amoebic dystentery	+	++	++	50
1b, IIb	Gastroenteritis	+++	+++		50
IIa	Skin sepsis and ulcers	+++	+	+	50
IIa	Trachoma	+++	++	++	60
IIa	Conjunctivitis	++	+	+	70
IIa	Scabies	++	+	+	80
IIa	Yaws	+	++	+	70
IIa	Leprosy	++	++	++	50
IIa	Tinea	+	+		50
IIa	Louse-borne fevers		+++		40
IIb	Diarrhoeal diseases	+++	+++		50
IIb	Ascariasis	+++	+	+	40
IIIa	Schistosomiasis	++	++	++	60
IIIb	Guinea worm	++	++	+	100
IVa	Gambian sleeping sickness	+	+++	+	80
IVb	Onchocerciasis	++	++	++	20?
IVb	Yellow fever	+	+++		10?

Table 1.3. The four mechanisms of water-related disease transmission and the preventive strategies appropriate to each mechanism

Transmission mechanism	Preventive Strategy
Water-borne	Improve water quality Prevent casual use of other unimproved sources
Water-washed	Improve water quantity Improve water accessibility Improve hygiene
Water-based	Decrease need for water contact Control snail populations Improve quality
Water-related	Improve surface water management Destroy breeding sites of insects Decrease need to visit breeding sites

Table 1.4. A classification of water-related diseases

Category	Example
1. Faecal-oral (water-borne or water-washed)	
(a) low infective dose	cholera
(b) high infective dose	Bacillary dysentery
2. Water-washed	
(a) skin and eye infections	Trachoma, scabies
(b) other	Louse-borne fever
3. Water-based	
(a) penetrating skin	Schistosomiasis
(b) ingested	Guinea worm
4. Water-related insect vectors	
(a) biting near water	Sleeping sickness
(b) breeding in water	Malaria

Table 1.5. Water-related diseases with their water associations and their pathogenic agents

Water-related Disease	Category from Table 1.4.	Pathogenic Agent
Amoebic dysentery	1b	C
Ascariasis	1b	D
Bacillary dysentery	1b	A
Balantidiasis	1b	C
Cholera	1a	A
Diarrhoeal disease	1b	H
Enteroviruses (some)	1b	B
Gastroenteritis	1b	H
Giardiasis	1b	C
Hepatitis (infectious)	1b	B
Leptospirosis	1a	E
Paratyphoid	1b	A
Tularaemia	1b	A
Typoid	1a	A
Conjunctivitis	2a	H
Leprosy	2a	A
Louse-borne relapsing fevers	2b	E
Scabies	2a	H
Skin sepsis and ulcers	2a	H
Tinea	2a	F
Trachoma	2a	B
Flea, louse, tick and mite borne typhus	2b	G
Yaws	2a	E
Clonorchiasis	3b	D
Diphyllobothriasis	3b	D
Fasciolopsiasis	3b	D
Guinea worm	3b	D
Paragonimiasis	3b	D
Schistosomiasis	3a	D
Arboviral infections (some)	4b	B
Dengue	4b	B
Filariasis	4b	D
Malaria	4b	C
Onchocerciasis	4b	D
Trypanosomiasis	4a	C
Yellow fever	4b	B

A = bacteria; B = Virus; C= Protozoa; D = helminth

E = spirochaete; F = fungus; G = rickettsiae;
H = miscellaneous

The big worries in municipal water supplies are that feacal pollution may allow organisms which cause such diseases as typhoid, where the infecting dose of bacteria to someone who drinks water is low, to be spread through water supplies and cause a large outbreak among the people who drink the water. Such infections are water borne diseases since the pathogenes are carried passively in water supplies and they are prevented by attention to water quality.

If the water quantity is very small, it may be impossible to maintain reasonable personal hygiene. Water for washing oneself, food, or utensils may be inadequate and therefore people may remain unwashed and this may allow skin infections to develop unchecked. This makes it easier for intestinal infections to spread from one person to another (through food handling). These then are water washed diseases and their prevention depends on availability, access to and quantity of water supply.

Some worm infections are not spread passively from person to person in the water. The parasite eggs or larvae which reach the water are not directly infective to man but are infective to specific inverterbrates eg. snails.

In these intermediate hosts, they undergo developments and after some time (days or weeks) they mature and may be shed into the water. These larvae are infective to man who is infected by drinking or on contact with the water. Such worms whose transmission is based upon an aquatic organism may be called water based infections. Prevention is by specific action to remove the intermediate host.

Lastly there are many infections spread by biting insects. Most of these breed in water eg. mosquitoes. Other insects capable of transmitting disease eg. tse tse fly only bite near water to which those lacking piped water go to draw water. These are water related diseases.

All the water borne, and some of the waterbased diseases depend on feacal access to domestic water sources and the transmission chain may be broken by safe disposal of human wastes as well as protection of water supplies. Some of the water washed intestinal infections may be reduced if better sanitary conditions reduce soiling of hands. In others, sanitation is more important than water because transmission is from feaces to soil and by direct penetration back through human skin.

1.3.1 Water Borne Diseases

Classical water borne diseases are due to highly infective organisms where only a few are needed to infect. Good examples are typhoid and cholera.

These two diseases occur as the common source and outbreak where a community water supply gets contaminated by feaces from a person suffering from or carrying one of the infections. Many people drink the water and a number of these fall ill from the infections at about the same time and the sudden appearance of a great number of sick people combined with their severity makes the diseases so feared.

Typhoid

This is the most cosmopolitan of the classical water borne infections. It produces a severe fever in man. Bacteria are ingested and very few are sufficient to infect. During the first few weeks of illness, they may be detected in the blood and are absent from excreta but subsequently they occur in large numbers in feaces originating from ulcers in the small intestines. Prevention is by immunization which lasts for many years. A small proportion of those who recover clininally continue to pass typhoid bacteria in their feaces for months or years and these carriers are the source of water borne infection.

Typhoid bacteria survive well in water but do not multiply there. Removal is by slow sand filtration and chlorination.

Cholera is similar to typhoid in some ways. The onset of diarrhoea is sudden and volume is immense so that untreated victim has a high probability of dying from dehydration within 24 hours or more. Infective dose is quite large but pollution levels in endemic areas are very high with immense feacal volumes full of bacteria and in dense human volumes.

Protection is by immunization (for a few months) so that improved water supply and sanitation is the most useful control. Other infections include Leptospirosis due to spirochaete which cause jaundice and 'weils' disease, Amoebiasis eg. Entamoeba histolytica causes dysentry, protozoal infection eg. giardiasis (diarrhoea).

1.3.2 Water washed diseases

Diarrhoea are the most important water washed diseases. They result from a range of infectious agents. All infections that can be spread from one person to another by way of water supplies may also more directly transmitted from feaces to mouth or through food. Infections may be reduced by provision of more abundant or accessible water of improved quality. This is particularly so in case of diarrhoeal diseases due to both bacteria and viruses as well as protozoa. All these infections fall to a low incidence under good hygienic conditions.

A second group of water washed diseases are infections of the body surface, the skin and the eyes. These include skin ulcers infected by bacteria, scabies due to small mite that burrow in the skin, fungus infection of the skin and trachoma. More water, together with improved personal hygiene are needed to reduce the frequency of these infections.

1.3.3. Water based diseases

These are all worm infections. Several are due to flukes or nematodes whose larvae depends on aquatic snails. The eggs pass from excreta to water and the larvae emerging from snails may be ingested with domestic water or on food plants or animals which acquire encysted larvae from the water. These include schistosome worms which can bore their way directly through the human skin. Others include Guinea worm etc.

1.3.4 Water related insect vectors or disease

These include the mosquito related diseases e.g. malaria, filariasis and they will not be covered here.

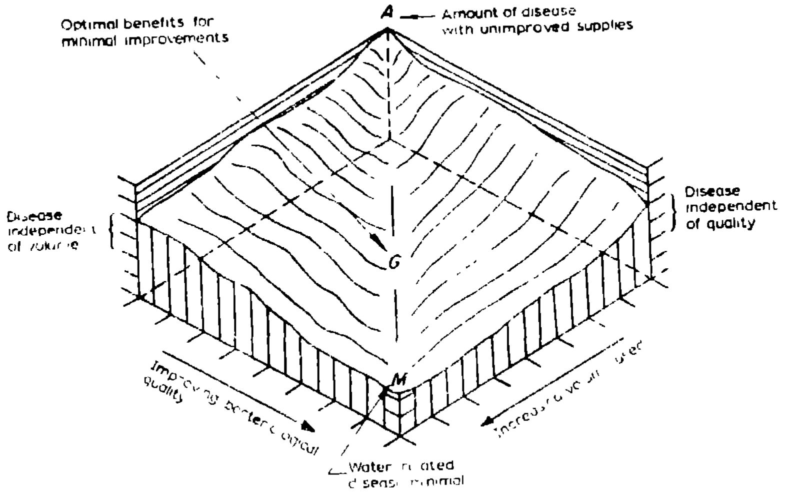


Fig.1 The generalized relation between volume and quality of water supplies and the burden of water-related disease A is the amount of disease with unimproved supplies At M water-related disease is minimal At G, optimal benefits are obtained for minimal improvements (Feachem et el 1972)

2. RAW WATER SUPPLY

Surface and underground sources are used for a variety of different purposes. In hot climates, the sources of water are variable in quality and microbiological quality. The presence of feacal material in water presents the most immediate hazard to health since feacal material from either human or animal sources may contain pathogenes. Diseases caused by feacal material may be due to protozoal or viruses.

2.1 Indicator Bacteria

It is calculated that bacteria constitute over 30% of the total wet volume of feaces. Feachem et al (1972). Counts of intestinal bacteria can therefore be used to give a very sensitive list of the extent of feacal pollution of water.

Bacterialogical tests for the detection of feacal pollution of water have been developed, using non pathogenic groups of bacteria selected on the basis of the following criteria:

a) numerous in feaces but not other material
b) counted by means of simple, reliable tests

c) more resistant than pathogenes to physical and chemical inactiviting agents

d) unable to grow in conditions outside the intenstine

The feacal caliform is a specific indication of pollution. Escherichia coli is exclusively feacal and constitutes over 90% of the caliform flora of the human intestine.

Feacal streptococci are occasionally used as indicator organisms especially where confirmation of dubious E. Coli results is required.

Tests for these indicators organisms are simple to perform on a routine basis.

2.2. Quality of raw water for potable supply

Microbiological quality for drinking water supply may be studied for:

a) assessment of the suitability of new water sources

b) routine surveillance of existing supplies

c) isolation of specific pathogens in epidemic situations.

For a new water supply it is necessary to have adequate knowledge of its sanitary quality, seasonal variations in quantity, and chemical quality must all be established to determine type and degree of treatment necessary.

Total agar-plate count and feacal coliform tests are performed over a range of hydrological conditions. These tests are often supplemented with feacal streptococcus test especially if the feacal coliform tests give equivocal results. Animals generally excrete much higher numbers of feacal streptococci than humans. The ratio of feacal coliforms to feacal streptococci in a water can indicate whether pollution is derived from human or animal sources.

Ratio of feacal coliforms to feacal streptococci greater than 4.0 strongly indicate predominantly human contamination with associated danger of human disease. (Feackem et al 1972)

Ratios of feacal coliforms to feacal streptococci less than 1.0 are mainly animal contamination . Where pollution occurs intermittently, the clastridium perfringes test is useful since the spares can survive in water for months after other indicator bacteria has died.

The microbiological quality of waters ranges from excellent (mainly underground sources) to grossly polluted. Surface water especially near urban areas are usually highly polluted.

3. Pollution Abatements

Pollution can be defined as the introduction into a body of water any substance in solid, liquid or gaseous form which may change the characteristics of the body of water as to disrupt its use as a source of domestic water, destroy or interfere with the growth and breeding of its natural flora and fauna, have deleterious effects on crops as a source of irrigation, interfere with its use as a recreational area and prejudice its function as a source of water for domestic, livestock and wildlife.
Meadows (1973)

3.1 Pollution sources

The quality of water in Kenya varies greatly from place to place, depending upon where it is found and with what it has come into contact with. Water coming from Mt. Kenya as snow melt contains practically no turbidity or dissolved solids at the onset. However, surface water becomes turbid as it travels over land by collecting soil particles, plant debris and animal wastes. When the small streams combine to form the tributaries of the Tana River, the water becomes red and very turbid by the time it reaches the Indian Ocean particularly during the rainy season.

The quality of the water is also affected by the use that is made of the water by man. Water used for irrigation may become saline; water used for municipal purposes gets fouled with domestic/ human wastes while industrial waste water may contain toxic substances.

3.2. Agricultural wastes

Agricultural practices produce wastes which affect water quality in various ways. Salinity which irrigation may add to water may make it unsuitable for other uses even for further irrigation. Some farming methods may destroy surface cover of grasses and trees and hence increase soil erosion and the turbidity in the receiving water. Some agricultural chemicals used as pesticides and herbicides may be toxic to fish and other aquatic life. Fertilizers can stimulate the growth of aquatic plants including algae which may clog raw water intakes and impart abnoxious tastes and odours to water.

3.3. Community wastes

Transporting and disposal of municipal waste water is one characteristic feature of a modern community.

Because of large volumes of water that are used for commercial, industrial and domestic purposes, the collection, treatment and safe disposal of sewage becomes an important community problem.

Where small amounts of water are used or where there are large distances between individual homes or other sources of wastes, sewage can usually be disposed off safely by soakage, (allowing it to seep into the ground depending on soil conditions, permeability, parasity etc.) As the population density increases the capacity of the soil to carry away wastes is exceeded and land disposal of the waste water is neither aesthetically desirable nor hygienically acceptable.

In densily populated areas, sewage is usually disposed of by discharge to a receiving body of water. The wastes are diluted to a point where they are not a nuisance. If the receiving water volume is not large enough to provide adequate dilution, a form of treatment is necessary to remove enough pollutants from the waste water and hence be released to lake aquatic environment.

Large towns and cities require huge amounts of clean water for their populations and industries.

Importation of water to augment local supplies normally creates a problem in that there is an increased amount of waste waters to be disposed off into receiving waters of constant volume. In Kenya most major towns and cities have grown in locations of limited water resources and this practically assures them of having localized water pollution problems that may be difficult or expensive to control. (World Health Organization Report No. 5 March 1973)

3.4 Industrial Wastes

The number of Kenyan industries that produce wastes that may pollute water resources is relatively small and many are located in Nairobi, Thika and Eldoret. These include textile industries, food processing, dairies and tanneries. Industries discharging directly to river are coffee, sugar, sisal, pulp and paper industries.

Where there is a sewerage system, local industry is encouraged to discharge its effluents into public sewers.

3.5 Waste water characteristics

Domestic waste water contains organic and inorganic matter as suspended, colloidal and dissolved solids. Their concentrations depend on the use to which the water has been put. Climate, health and habits of the people have a marked effect on the waste water characteristics.

The presence of industrial wastes in the public sewers can substantially alter the nature of waste water. The amount of water used per per son can also affect the concentration. Thus, waste water characteristics vary from city to city and also from season to season.

Raw domestic waste water is mainly organic and contains carbon, nitrogen and phosphorous among others with relatively high concentrations of micro organisms. They are readily putrescible and biological degradation of organic matter proceeds even as the wastes flow through the sewers. Table 3.1 gives characteristics of fresh sewage. Note that values given are in terms of g/capita for design purposes. Values given in terms of mg/litre are obscured by the fact that water usage varies markedly between communities.

Normally biochemical oxygen demand (BOD) average around 54g per person per day where sewage collection is efficient.

Table 3.1 shows the fate of pollutants discharged by man as a result of his industrial, agricultural and urban activities.

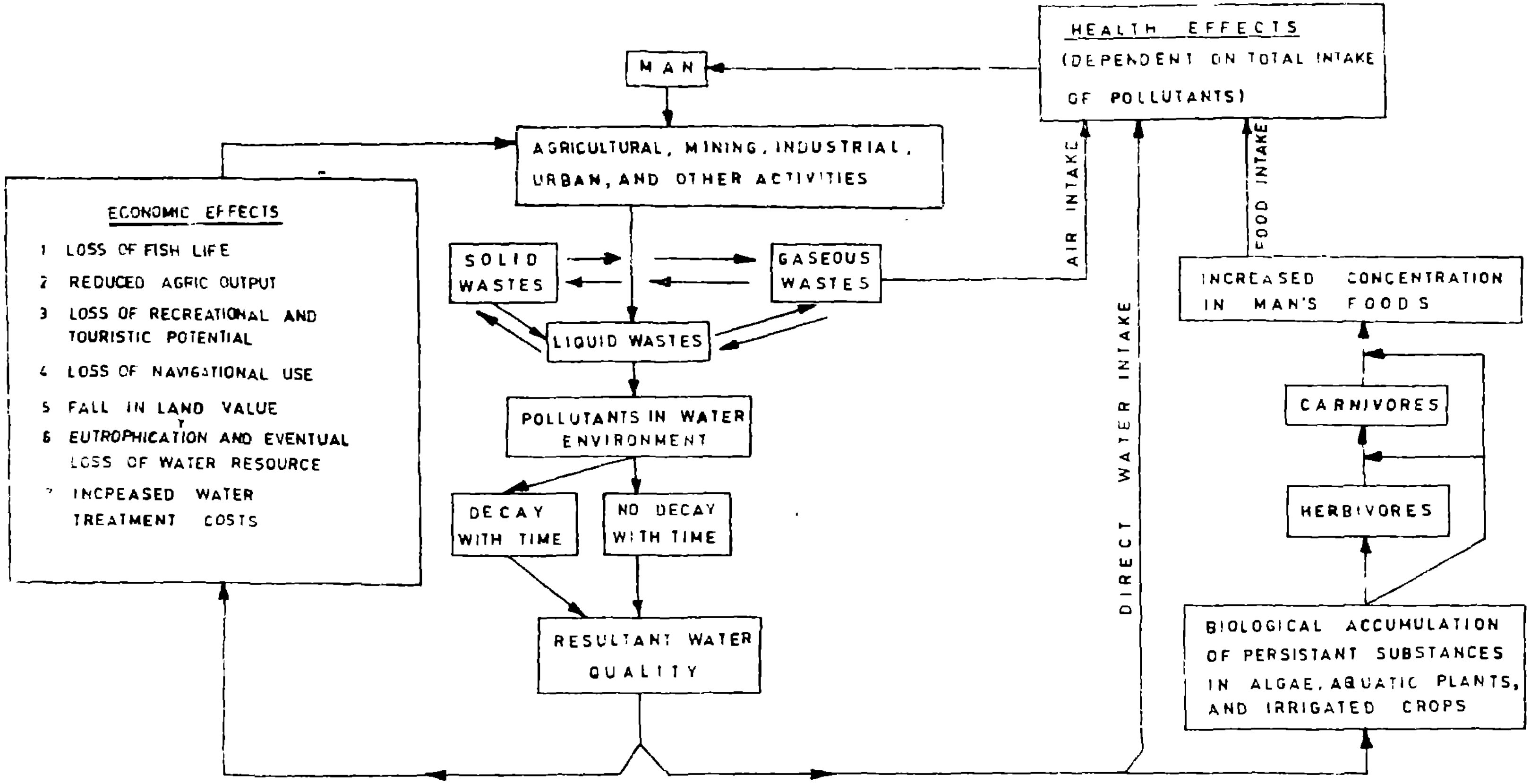


Fig. 3.1 The relationship between man and the water environment. **(Arceivala, 1981)**

Domestic waste is composed of human wastes and there are principally organic wastes.

Wastes + oxygen + bacteria = oxidized wastes + New bacteria.

As mentioned earlier the strength of the waste depends on the quantity of organic matter and the water associated with it. The strength of the waste is usually judged on the basis of BOD and in this paper, the BOD value refers to the 5 day, 20^{o} C value.

Below is a general classification as given by (Mara el al 1972)

Strength	BOD mg/l
Weak	200 or less
Medium	350
Strong	500
Very strong	750 or more

Waste water treatment has three aims:

a) destruction of pathogens especially causative agents of water related diseases which are associated with domestic wastes (category 1 Table 1.5)

b) To convert the wastes into a re-usable resource and conserve water and nutrients

c) To prevent pollution of surface and ground-water into which effluent escapes.

To achieve its aims, waste water treatment must produce an effluent of certain quality. Generally the required effluent quality is assigned as BOD_5 is 20mg/l and suspended solids is 30mg/l (Meadows Nov. 1973.) For these standards to be meaningful, certain basic information should be available and these include:

a) the amount of dilution available in the receiving water body

b) the subsequent downstream of the water

c) the self purification characteristics of the water body

d) the composition of the effluent

e) the existing pollution load upstream of the outfall and as much knowledge of its ecology as possible

f) the water quality characteristics of the receiver that will affect the degree of toxicity exerted by the effluent.

4. WASTE WATER TREATMENT METHODS

In every country there are many competing demands on the limited amount of funds for development.

Waste water treatment, although important from public health, ecological, aesthetic and other points of view is generally likely to be given a low priority. Therefore, within the limited funds avialable, the designer is called upon to select a method of waste water treatment which will be capable of meeting the environmental quality objectives and giving the right degree of treatment required before discharge to rivers or coastal waters.

From among the treatment methods qualifying for consideration, those having a bearing on local conditions such as climate, land availability, equipment, power, need of imported spare parts, availability of skilled personnel and facilities for operation and maintenance of the plant are selected.

Over the years, it has become increasingly apparent that simple, low cost waste water treatment does not necessarily mean low quality treatment. Without sacrificing quality, ways and means of reducing the costs and complexities of waste water treatment have been developed and should be welcomed by all engineers who would like to stretch the public funds available as far as possible to meet the rising expectations of the people and build plants that will work under various construction and operational difficulties. The method which is technologically simplest, economically competitive, and operationally capable of meeting effluent quality requirements must be preferred if a project is to be viable.

A few methods of waste water treatment are available in Kenya for treatment of both domestic and industrial wastes. These are listed below in increasing order of mechanization:

a) Waste stabilization ponds (lagoons with or without anaerobic ponds preceeding them

b) Mechanically aerated lagoons or ponds

c) Oxidation ditches (pasveer type) and other aeration

d) Activated sludge process and trickling filters

Anyone of these methods should give a high degree of removal. Item (d) above may seem out of place in this paper which is emphasizing ponds as treatment method but it must be recognized that in Kenya before independence in 1963, most of the treatment plants were trickling filters. The trend these days is shifting to waste stabilization ponds, oxidation ditches and aerated lagoons. This is because they are cheaper to build and easier to operate.

At conventional treatment plants, they generally constitute screens, flow recorders, primary sedimentation, trickling filters and humus tanks.

To get a clearer picture of the waste water treatment methods that are in use in Kenya, Table 4.1 show their construction and use pre 1963 upto 1982 (Stoveland et al 1982)

Table: 4.1 Table showing types and number of treatment plants in Kenya (Operated by Local Authorities) Stoveland et al 1982

TIME BUILT	TREATMENT METHOD			
	CONVENTIONAL TREATMENT WITH TRICKLING FILTERS	STABILATION PONDS	OXIDATION DITCHES OR AERATED LAGOONS	TOTAL NUMBER
Before Independence	12	3	0	15
1963 - 1975	0	15	1	-
1975 - 1982	0	3	1	35
Under construction	2	3	4	43
Total	14	24	6	-

4.1 SEWAGE TREATMENT PLANTS USED IN SELECTED TOWNS IN KENYA

Large towns and cities require huge amounts of water to sustain the needs of their population and industries. The importation of water to augment local supplies almost invariably creates a water pollution problem for larger and larger volumes of sewage must be disposed off in receiving waters of virtually constant size. Almost without exception, the cities and towns in Kenya have developed in locations of limited water resources and this practically assures them of having localized water pollution problems that may be difficult or expensive to control (Report No.5 W.H.O. 1973)

4.1.1 Nairobi

The City of Nairobi is situated on the Athi Plain at the edge of Rift Valley in the central part of the country began as a rail road town early this century. Water resources in the area are extremely limited and water is brought in from sources in the Aberdares Range by pipeline. The Nairobi River which serves as a receiving water for the treated effluents for Eastleigh and Kariobangi sewage treatment plants is very small. Each of these plants employs trickling filters for secondary treatment. The BOD_5 of the river below Eastleigh plant during dry weather has been measured at 100mg/1 (1972) Report No. 5 WHO 1973 Further downstream BOD_5 is still increased by discharge of final effluent and by passed flow from Kariobangi sewage plant with BOD depending on the amount of sewage being by-passed at any given time. Further downstream the newer Dandora treatment plant which comprises of facultative and maturation ponds discharge their effluent into the same river.

4.1.2 Mombasa

The second largest town of Kenya gets its water supplies from Mzima Spring and wastes are disposed of in the Indian Ocean.

Treatment plant in Mombasa was built in 1964 and has a capacity of 3700 m^3/d primary treatment with outfall far out in the Indian Ocean. There is also an oxidation ditch in Changamwe/Kipevu area.

4.1.3 Nakuru

The plant was built in 1956 and with a design flow of 4000 m^3/d and comprises of trickling filters. Effluent is discharged into Lake Nakuru. This has been augumented by new lagoons to provide for expected industrialization and consequent growth of population in the community.

4.1.4 Kisumu

The treatment plant is conventional employing trickling filters for secandary treatment. Design capacity is about 6800^3/d. Final effluent is into Kasat River which flows to Lake Victoria. In addition there are WSP recently built.

4.1.5 Eldoret

Design capacity of the original sewage treatment plant was 1500m^3/d and finally 4500^3/d. The treatment plant uses trickling filters and discharge is into sosian river. Waste stabilisation lagoons have been built to augument the existing old plant.

4.1.6 Thika

There are two treatment plants in Thika Municipality. The first was constructed in 1956 employs Imhoff tanks for primary treatment and trickling filters for secondary treatment. Effluent is discharged into Thika river.

A new set of 20 ponds has replaced the old conventional works in 1972 and this alleviates the problem. There are many industries in Thika which discharge very strong waste water in the sewer system.

4.1.7 Nyeri

The original plant was designed as a secondary treatment plant only employing trickling filter. Effluent is discharged into the Chania River which provide adequate dilution. The trickling filters do not operate frequently as intended and the humus tanks act as a primary settlement tank. A new treatment plant is under construction and should be ready in the near future.

4.1.8. Embu

Embu has a sewer system comprising of a circular primary pond and a small maturation pond capable of treating nearly $4000m^3/d$ per day. The receiving water for the effluent is the Rupingazi River.

4.1.9 Kitale

The original sewerage treatment plant was constructed in 1958. It comprises of preliminary and primary treatment followed by trickling filters and maturation ponds. In addition a new waste stabilization pond plant is in operation.

4.1.10 Karatina

The treatment plant consists of screens and 4 ponds in series and the outfall is into Ragati River.

4.1.11 Others

Other treatment plants in Kenya include; Meru, Molo, Ngong, Sotik, Kericho, Bungoma, Homa Bay, Nyahururu, Limuru, Muranga and Nanyuki. (Report No.5 WHO 1973)

5. WASTE STABILIZATION PONDS (WSP)

Waste stabilization ponds are large shallow basins enclosed by earthen enbankments in which raw sewage is treated by natural processes involving algae and bacteria. They have a low rate of oxidation and the hydraulic retention times are in the range of 30-50 days.

Fig. 5.1 Circular Waste Stabilization Pond

Purification of wastes is by the following continuous processes:

a) sedimentation of settleable solids

b) reduction of BOD by biochemical oxidation of dissolved and suspended organic matter

c) anaerabic digestion of benthal deposits and the oxidation of the products of such digestion

d) reduction in the concentration of pathogenic organisms due to the inhospitable environment and long detention times required.

See Fig. 5.2 for BOD removal in facultative ponds

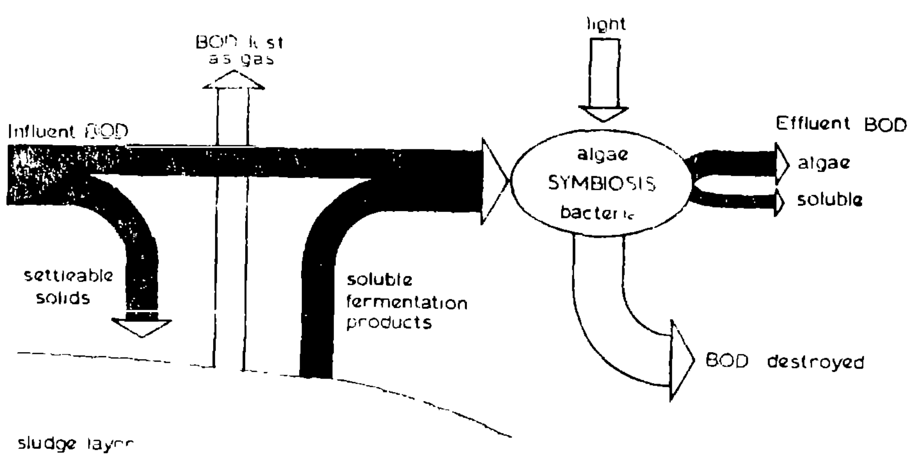


Fig. 5.2 Pathways of BOD removal in facultative stabilization ponds (after Marais 1970b) (Mara 1972)

The rate of oxidation of organic compounds exceeds the rate of oxygen supply by surface aeration and the extra oxygen required is supplied by algal photosynthesis. Carbon dioxide usage by algae exceeds the supply diffusing in from the atmosphere and the balance is provided by bacteria. This symbiotic relationship is a characteristic of waste stabilization ponds. Fig. 5.3

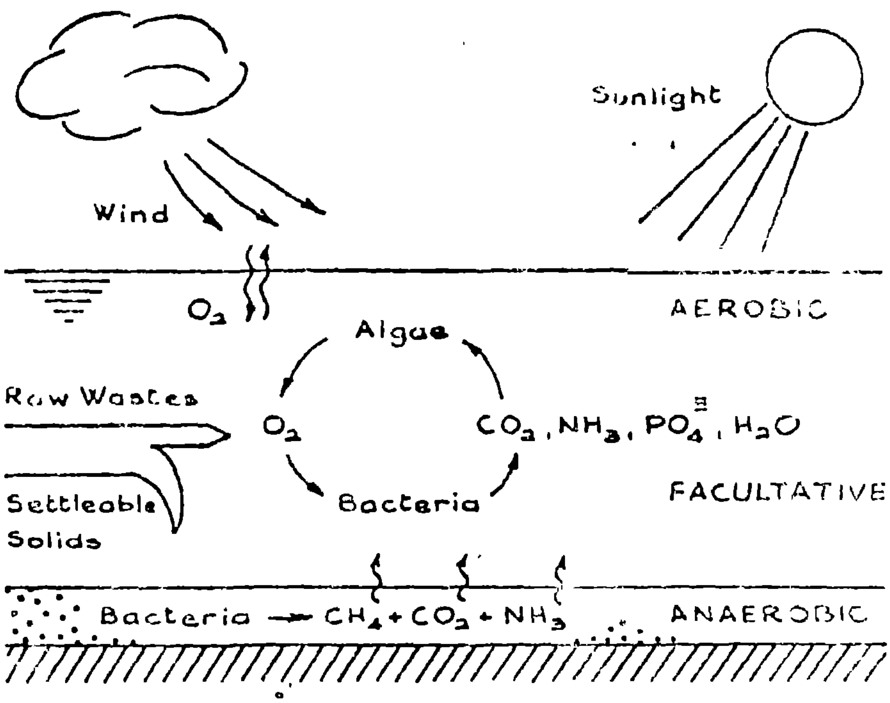


Fig.5.3 : WASTE STABILIZATION POND MECHANISMS
(Fraser Nov. 1973)

5.1 Mixing

Wind and heat are major factors which influence the mixing within ponds. Mixing minimizes short circuiting and ensure a reasonable uniform vertical distribution of BOD algae and oxygen. The depth of wind induced mixing depends largely on the distance the wind is in contact with the water and this unobstructed is about 100m for maximum mixing. (Mara 1972)

5.2 Types of Ponds

Ponds are generally classified according to the nature of biological activity taking place within them. Such a classification is shown below:

a) Facultative ponds

b) Aerobic ponds

c) Anaerobic ponds

d) Maturation ponds

5.2.1 Facultative ponds

These are the most common and they normally receive raw sewage which has only received preliminary treatment. The term 'Facultative' refers to a mixture of aerobic and anaerobic condition and in a facultative pond, aerobic conditions are maintained in the upper layers while anaerobic conditions exists towards the bottom.

As depicted in Fig. 5.3 some of the oxygen required to keep the upper layers aerobic comes from rearation through the surface while most of it is supplied by photo-synthetic activity of algae which grow in the pond, where both nutrients and incident light energy are available. The pond bacteria use the 'algal' oxygen to oxidise the organic waste matter.

The end products include carbon dioxide which is readily used by algae during photosynthesis since their demand is higher than their supply from atmosphere.

Since photosynthesis is light dependent, there is a diurnal variation in the amount of dissolved oxygen present in pond (fig. 5.4) and a similar fluctuation in the level below the surface at which dissolved oxygen concentration becomes zero. The pH of the pond contents also follows a cycle increasing with photosynthesis to a maximum at peak demand when algae remove CO_2 from solution more rapidly than it is being replaced by bacterial respiration. This causes the bicarbonate ions present to dissociate to provide more CO_2 and alkaline hydroxyl ion which increases the pH

$$HCO^- \longrightarrow CO_2 + OH$$

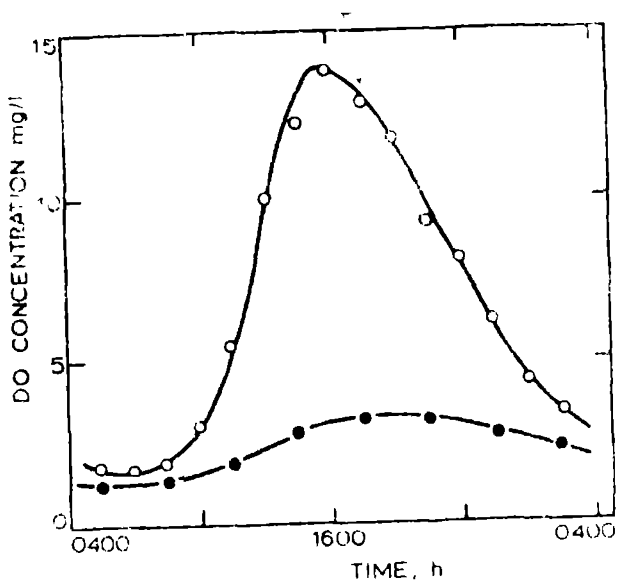


Fig. 5.4 Diurnal variation in dissolved oxygen, ○, top 200 mm of pond, ●, 800 mm below surface

(Mara 1972)

5.2.1.1 Sludge Layer

When sewage enters the pond most of the solids settle to the bottom and form a sludge layer and at temperatures greater than 15°C anaerobic digestion of sludge occurs. Mara (1972) has shown that at temperatures greater than 22°C evolution of methane gas bouys sludge particles up to the surface to form sludge mats.

The soluble products of fermentation diffuse into the bulk of liquid where they are oxidised further. Seasonal variation of the rate of fermentation (which increases sevenfold with each 5°C rise in temperature) makes the BOD_5 in pond almost constant throughout the year despite temperature changes. (Mara 1972)

5.2.1.2 Depth

Pond depth of less than 1m do not prevent the emergence of growth which encourages breeding of mosquitos. In arid areas evaporation may make it necessary to have pond depth of 2m to minimize surface area. Generally pond depth is around 1.6m.

5.2.2 Aerobic W.S.P. (High Rate)

Aerobic conditions exists throughout the shallow depth of 0.15 - 0.5m. Algae production is maximized by ensuring that "oxypause" is at bottom of pond. If deeper ponds are required, pond mixing by pumps or surface aerators is necessary.

5.2.3 Anaerobic W.S.P.

Essentially these are anaerobic digestors and may be used to pretreat strong wastes which have a high solids content. The solids settle to the bottom and are digested anaerobically; the partially classified supernatant liquor can be discharged into a facultative pond for further treatment. Successful operation of anaerobic ponds depends on the balance between acid-forming bacteria and methanogenic bacteria. Temperature 15°C is necessary. pH must be greater 6. Economics of land are achieved by use of anaerobic ponds. To conserve heat and maintain anaerobic conditions, depth up to 6m have been used. (Fraser 1973)

5.2.4 Maturation Ponds

These are used as a second stage to facultative ponds. Their main function is the destruction of pathogens.

Feacal bacteria and viruses die off reasonably quickly due to the harsh environment. The cysts and ova of intestinal parasites whose relative density is about 1.1 settle to the bottom of pond and due to the long retention time they die. BOD removal in maturation ponds is low. They generally have shallower depths than facultative ponds.

5.3 Waste Stabilization Usage

From a survey carried out in 1964-1967 by W.H.O. it was established that waste stabilization ponds are in use in at least 39 countries. Such ponds are in use from the polar areas to the equator Gloyna (1971).

The organic and volumetric loadings were found to vary considerably but BOD removal efficiencies for comparable areas and loadings seem fairly uniform throughout the world.

5.3.1 Waste Stabilization ponds in Kenya

By 1973 there were waste stabilization ponds in 35 locations in Kenya either in operation or under construction. Fraser (1973)

Ten years later, more W.SP. has been built in various locations including Nairobi, Naivasha, Nyahururu, Busia, Kitale, Isiolo and Eldoret.

5.3.2 Design of Waste Stabilization Ponds in Kenya

Facultative Ponds

The design of WSP systems in Kenya in the past has been largely preoccupied with BOD removal which takes place mainly in the first pond. Designers have often used their empirical loading rate to calculate the total area of a pond system (facultative and maturation ponds) rather than the area of facultative pond alone, leading to immediate over loading of the facultative pond. Fraser (1973)

It is recommended that regardless of whether the ponds provide complete or secondary treatment, two ponds in series should always be provided in preference to a single pond. (Report No. 9 WHO 1973.)

The recommended method for designing of facultative ponds is based upon the formulae suggested by Marais in his 1966 paper but modified by Gloyna (1971).

There are two basic equations:-

$$RT = \left\{\frac{Lo}{Lp} - 1\right\} \frac{1}{KT} \quad \text{----------} \quad 1$$

$$Lp = \frac{600}{(0.18d + 8)} \quad \text{--------------} \quad 2$$

Where

RT = required detention time in days at temperature T

Lo = the oxygen demand of incoming sewage in milligrammes per litre (if the ponds provide secondary treatment then Lo may be taken as the BOD; where the pond provide complete treatment, then for the primary pond Lo should equal the Ultimate Oxygen Demand (UOD) which for domestic wastes is approximately equal to 1.6 times BOD_5

Lp = the BOD of pond effluent mg/l

KT = the breakdown rate per day of sewage organics at temperature T. The units being day $^{-1}$

d = the depth of pond in metres and this is 1.75 metres in Kenya

Values of KT at various temperatures are given below in Table 5.1

Table 5.1

Temperature Degrees centigrade	KT^{-1} days
10	0.12
14	0.22
18	0.32
22	0.42

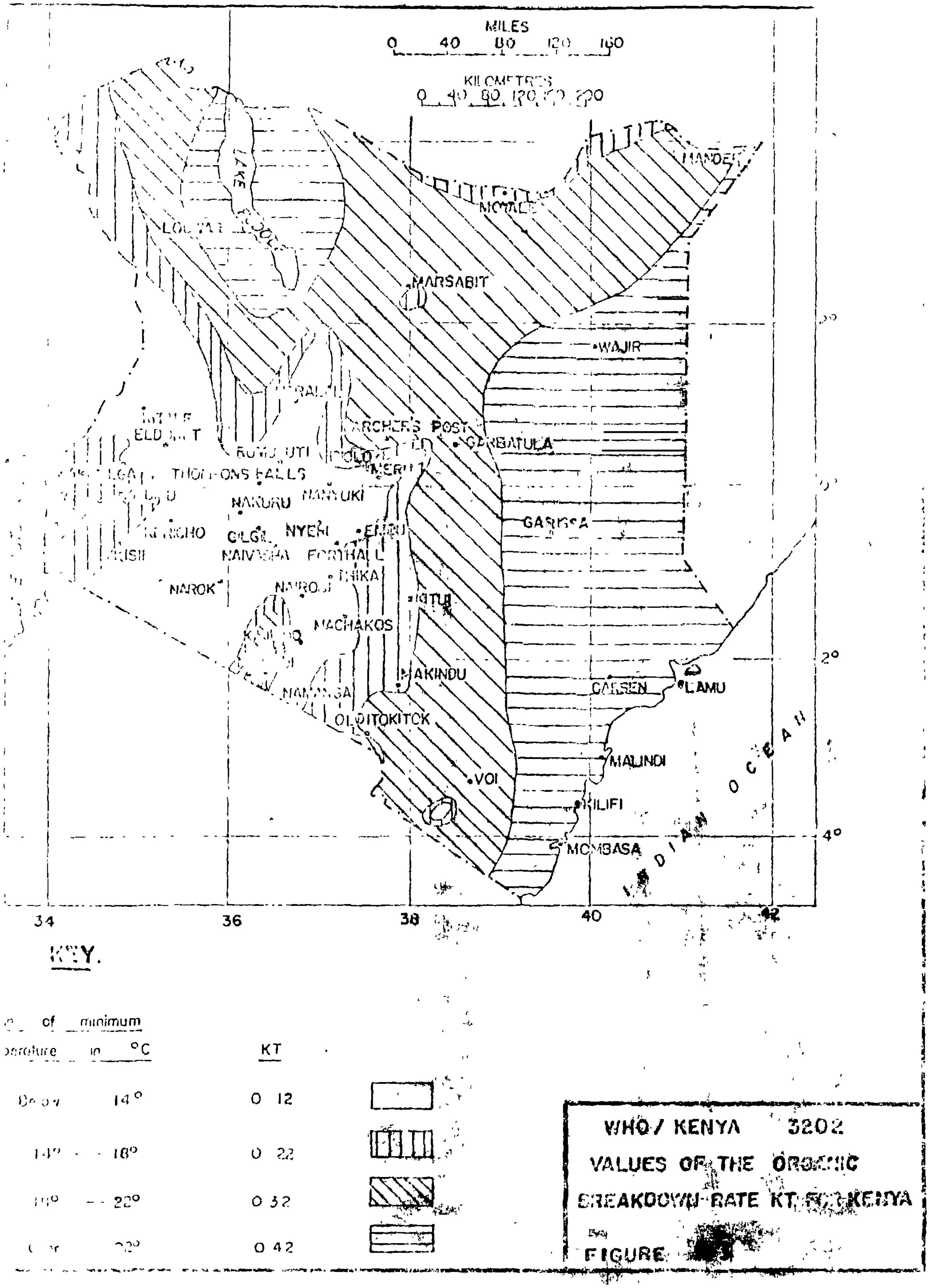
Values of KT at various temperature from Report No. 9 WHO 1973

Since ponds are less efficient at lower temperatures, T is taken as the annual "mean of minimum" temperature for the area in which pond will be located.

On this basis Kenya is divided into 4 zones each with its KT value; these zones are shown on Fig. 5.5

Values of organic breakdown Rate KT for Kenya

(Report No. 9 WHO 1973)



Example showing how to use design formulae 1 and 2

Given to design two facultative ponds in series to treat sewage contributed by 1000 persons to a BOD not exceeding 20 milligrams per litre and assuming a value of KT = 0.12

Solution

Assume

a) 1 person contributes 55 grams of BOD per day in say 80 litres of sewage

Therefore 1000 persons contribute 55 kilogrammes of BOD and 8×10^4 litres of sewage each day.

BOD concentration of sewage is $\frac{55 \times 10^6 \text{ mg}}{8 \times 10^4 \text{ litre}}$

$$= 690 \text{ mg/l}$$

The UOD concentration of sewage is roughly

$$1.6 \times 690 \text{ mg/l} = 1100 \text{ mg/l}$$

If d = 1.75m, substituting in Formula 2

$$Lp = \frac{600}{(0.18d + 8)} = 72 \text{ mg/l}$$

This is the BOD of the primary pond

Substituting this value for Lp in Formula 1

$$RT = \left(\frac{1100}{72} - 1\right) \frac{1}{0.12} = 118 \text{ days}$$

Surface area of primary pond

$$= \frac{\text{Daily Flow } (m^3) \times RT}{\text{Depth (in m)}} = 5400m^3 = 0.54ha$$

Organic Loading of primary pond

$$= \frac{\text{BOD concentration (Kg/litre) x Daily flow (in litres)}}{\text{Surface area (in hectares)}}$$

$$= \frac{6.9 \times 10^4 \times 8 \times 10^4}{0.54} \quad \frac{Kg}{L} \times \frac{L}{day} \times \frac{1}{ha}$$

$$= 102.5 \ \frac{Kg\ BOD}{ha\ day}$$

<u>Secondary Pond</u>

Formula 2 has no significance

$RT = \left\{\frac{Lo}{Lp} - 1\right\}$ Lo = 72 mg/1 ie effluent from primary pond

Lp = 20mg/1 given as the required system effluent

$$RT = \left\{\frac{1100}{72} - 1\right\} \frac{1}{0.12} = 118 \text{ days}$$

Surface area of primary pond

<u>Surface area</u>

$$A = \frac{80 \times 22}{1.75} \quad \frac{M^3}{day} \times \frac{days}{m}$$

$$= 915 \ m^2$$

$$= 0.09 \text{ ha}$$

<u>Organic Loading of Secondary pond</u>

$$= \frac{\text{BOD concentration (kg/1) x Daily Flow (L)}}{\text{surface area (ha)}}$$

$$= \frac{7.2 \times 10^{-5} \times 8 \times 10^4}{0.09} \quad \frac{Kg}{L} \times \frac{L}{ha\ \ day}$$

$$= 64 \ \frac{Kg}{ha} \ \frac{BOD}{day}$$

Tables 5.2 and 5.3 give comparative results for different values of T found in Kenya Report No. 9 WHO (1973)

Table 5.2 Primary Pond design : comparative results for different temperatures

T degrees centi grade	KT $^{-1}$ (days)	RT (days)	Surface area (ha)	Surface Loading (kg BOD per ha per day)
10	0.12	118	0.54	102.5
14	0.22	64	0.29	190
18	0.32	44	0.20	260
22	0.42	34	0.15	360

Table 5.3 Secondary Pond design; comparative different temperatures

T degrees centi grade	KT -1 day	RT (days)	Surface area (ha)	Surface Loading (Kg BOD per ha per day)
10	0.12	22	0.09	64
14	0.22	12	0.05	118
18	0.32	8	0.035	170
22	0.42	7	0.025	224

* it should be noted that RT should never be less than 7 days even when calculations show that theoretically a shorter period of detention is adequate.

Maturation Ponds

Maturation ponds are aerobic waste stabilization ponds, normally 1 meter deep.

In order to produce an effluent with BOD 25mg/l it has been found that two maturation ponds each with retention period of 7 days are required. This assumes that BOD_5 of the effluent of facultative pond is less than 75mg/l. Mara (1972)

6. SITES SELECTED FOR STUDY

To evaluate efficiency of WSP in Kenya, three different pond systems were selected. These selected locations are sampled and analysis carried out on

a) the raw sewage

b) primary pond effluent

c) secondary pond effluent

d) Maturation pond effluent

In short grab sampling was done at all pond effluents. Such measurements as pH, temp or flow were measured if possible. The analysis include BOD_5, suspended solids, COD, and E Coli and this was carried out at the University of Nairobi Environmental Health Engineering Laboratory.

Standard method for analysis were employed so that the data obtained can be compared with other data.

The selected W.S. Ponds are

a) Nairobi WSP at Dandora

b) Karatina W.S.P.

c) Embu W.S.P.

6.1.1. DANDORA W.S.P. PHASE I

Siting of Works and Types of Ponds:

These W.S.P. were built to augment the two existing plants which are of the trickling filter type.

These ponds are sited sufficiently far from built up areas (in order to avoid nuisance arising from smell, insects e.t.c.). This was also to allow room for futher growth of the city and to ensure that Nairobi Airport could be drained to this site.

It was essential to ensure that the length of outfall sewer to be laid will not be too long so as to avoid excessive costs.

There is a total of 8 ponds consisting of 2 parallel lines of 4 ponds each. The first 2 ponds in each line are facultative ponds and the other 2 are maturation ponds. This means that in each line there is

a) primary facultative pond

b) secondary facultative pond

c) primary maturation pond

d) secondary maturation pond

6.1.2. Design Values:

Design waste water flow	=	30,000 m^3 /d
Design B.O.D.	=	340 mg/1
Design suspended solids	=	360 mg/1

The sizing of the ponds is as follows

a) primary facultative ponds

length	-	704 m.
Breadth	-	305 m.
water depth	-	1.75 m

Nominal retention times is 24.5 days

b) Secondary facultative ponds

length	-	295 m.
Breadth	-	305 m.
water depth	-	1.75 m.

Nominal retention times = 10 days

c) Primary Maturation ponds

length	-	291 m.
Breadth	-	305 m.
Water depth	-	1.25 m.

Nominal retention times = 7 days

d) Secondary Maturation ponds

length	-	295 m.
Breadth	-	305 m.
Water depth	-	1.25 m.

Nominal retention times = 7 days

6.1.3. **Pond Layout**

At Dandora, pretreatment include automatic coarse screens, storm water overflow and venturi flume. Inlet works consists of 2 constant velocity channels in which automatic screens with 25 mm opening facultative.

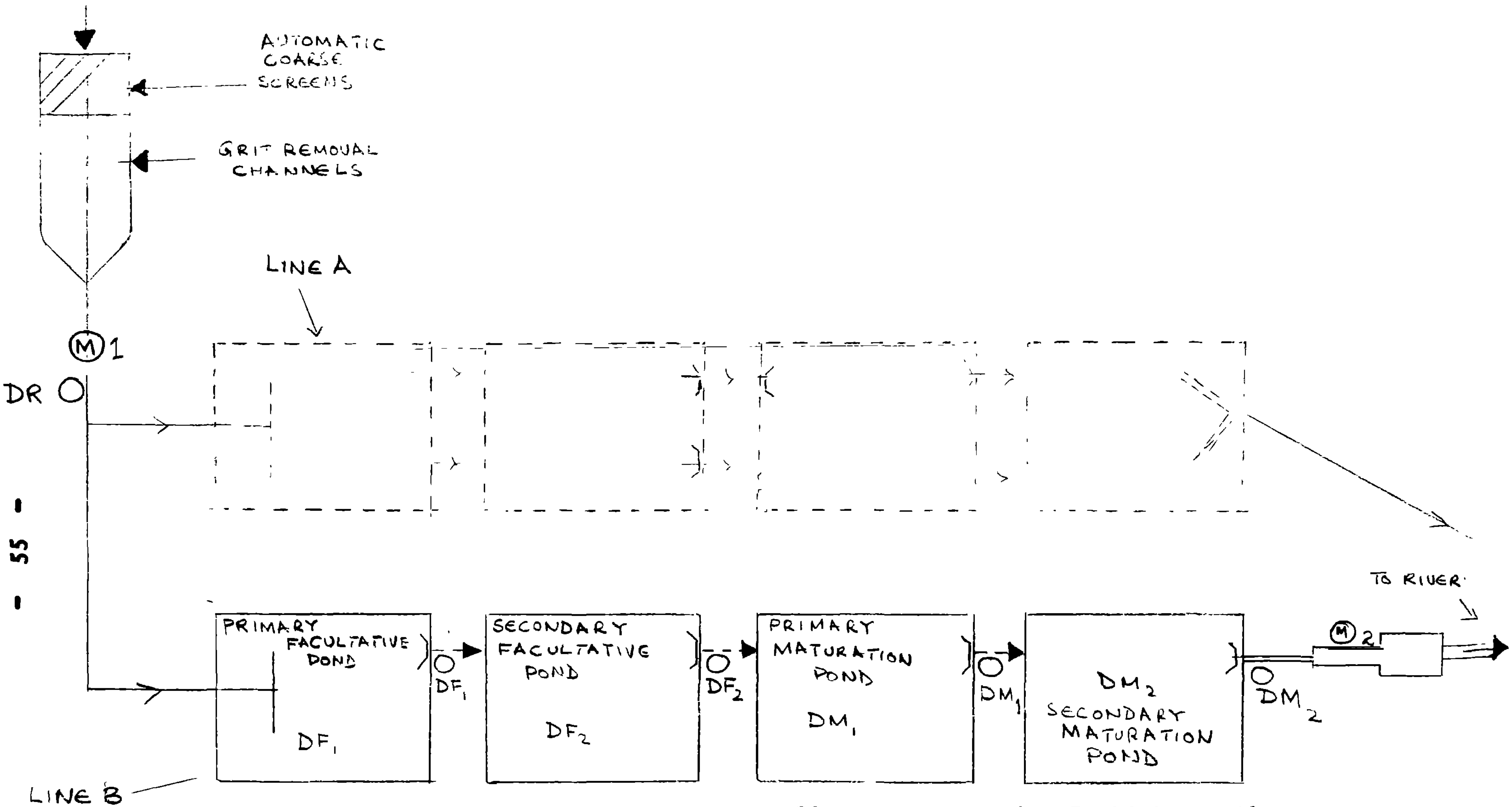
Provision has been made to have washouts in each pond and also to isolate any pond for desludging See fig. 6.1 approximate layout.

At the start of study period the two maturation ponds on Line A had been emptied for remedial work. This made it necessary to sample Line B only. Raw waste water sample was taken after the screen while the other samples were taken at the pond outlets of all ponds on Line B. Towards the end of the study period the two maturation ponds started filling up.

Observation during the study period showed the ponds to be bright green in colour. There was a little bit of scum at the corners of the ponds but not much. The whole place had grass cut and the paving slabs are all in place. During early morning there was foaming at pond outlet to the river.

A few species of duck and stork thrive in in the ponds and about 10 hippos have their home in the ponds. These hippos are docile and do not cause problems to the plant operators, however, they sometimes raid the surrounding farms and cause havoc to maize patches.

The sampling was done mostly around 10.00 - 12.00 hours in all cases and the samples were in the laboratory by 14.00 hours.



Note: O_{DR} —— DM_2 **indicates sampling points on line B which was the line studies**

M_1 **and** M_2 **are influent and effluent flow meters**

Fig. 6.1 **POND LAYOUT AT DANDORA** (Not to scale)

6.2 EMBU W.S.P.

This system comprises of one circular pond and a small maturation pond.

The first pond is circular with a middepth diameter of 110m and water depth of 1.37m. The sewage is conveyed to the pond via a screen and a submerged inlet pipe and at the end of the inlet pipe there is a scumboard. The pond is furnished with a baffle wall to avoid short circuiting. The outlet is near the centre of pond, where an inlet box is placed. From the inlet box, the water is conveyed in a concrete pipe at the bottom of the pond to the second pond.

Fig. 6.2 EMBU PRIMARY POND

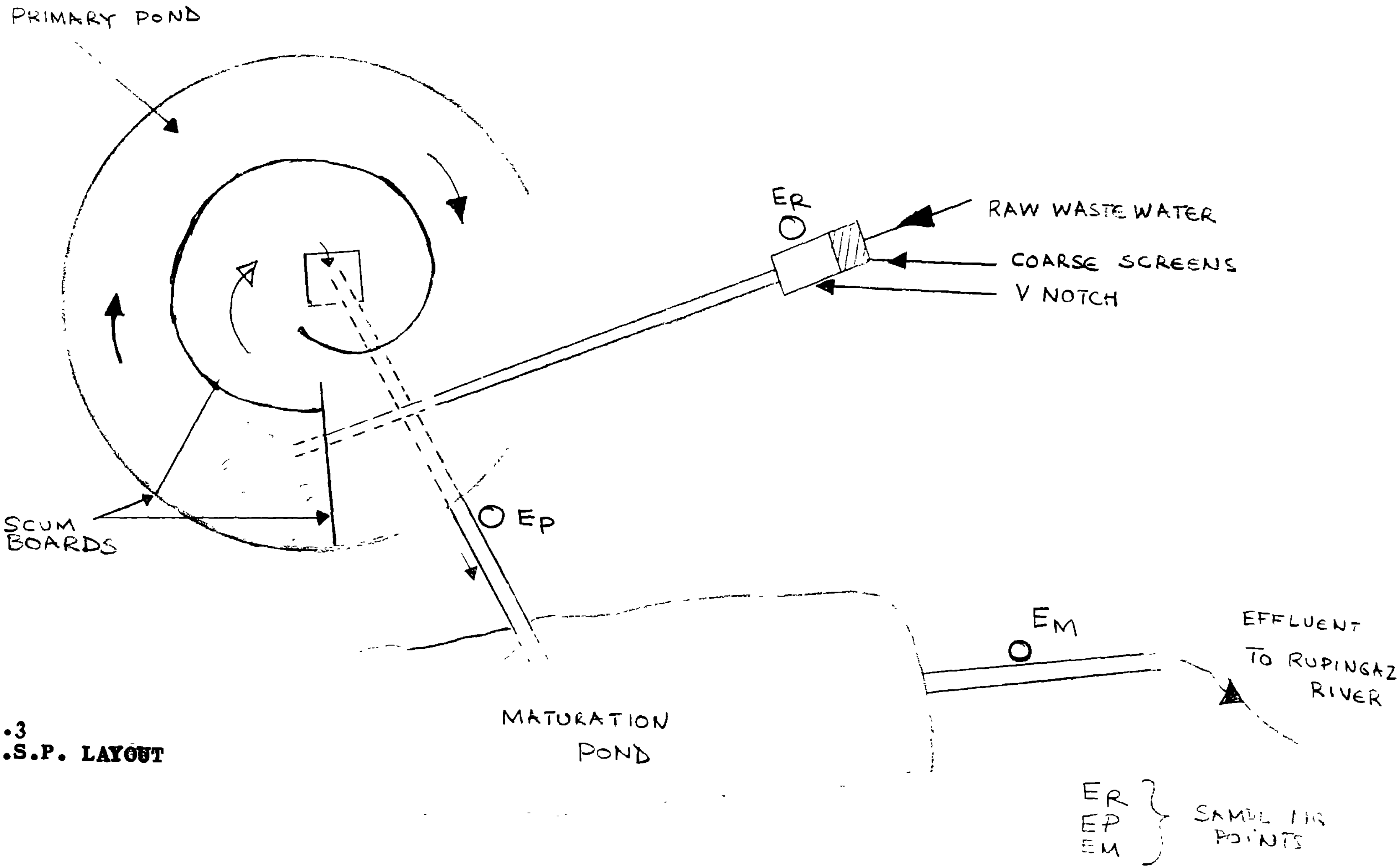


Fig. 6.3
EMBU W.S.P. LAYOUT

The slope of the embarkments for the first pond is 1:2.5. on the "wet" side and 1:2 on the "dry" side. The embarkments are rendered masonry giving protection against waves and growth of vegetation. At the inlet the masonry is extended to the crest to serve as temporary area for removal of surface scum.

The second pond was originally constructed as a temporary pond during the desludging of the first pond but after desludging, the pond was used as a secondary pond. It has an area of about 2000 m^2 and depth varies from 1m - 2m. It has no botton lining and there is a lot of seepage and at times there is no outlet flow.

The outlet of this pond goes to a small stream which later joins the Rupingazi River.
There is no detailed calculations of the sewage treatment plant available but the main design figures appear to be as follows (COWI Consult 1983).

Population served	9000 persons
Estimated dry weather flow	682 m^3/d
Total pond surface area	12.141 m^2
Total Retention Time	65.75 days

The ponds had desludged from May to August 1983 and they started filling around September to December.

6.3. KARATINA W.S.P.

This waste water treatment plant caters for Karatina Municipality and it is composed of 4 ponds. These are

a. Primary Facultative pond

b. Secondary Facultative pond

c. Primary Maturation pand

d. Secondary maturation pond

The dimensions for the ponds is as follows:-

Primary Facultative Pond
Area = 13,000 m^2
Depth = 1.10 m

Secondary Facultative pond
Area = 4130 m^2
Depth = 1.65 m

Primary Maturation Pond
Area = 1850 m^2
Depth = 1.65 m

The raw sewage is screened and the flow is measured by a 45^o V - notch. The daily average flow is about 6.5 l/sec which is approximately 560 m^3/day.

The pond area is well taken care of and the grass on the embarkment/trimmed. Only signs of deterioration /is is that plastic membranes used to line the botton of the ponds is floating on the surface in the Secondary facultative pond.

Sampling was done at the inlet of raw sewage and at all the pond outlets and five samples were collected each time. The labelling for the samples was as follows:-

KR for Raw Sewage

KP_1 for Primary pond effluent

KP_2 for Secondary pond effluent

KM_1 for Primary maturation effluent

KM_2 for Secondary maturation effluent

At the start of the study period the algae in the pond was green throughout and there was no offensive smell.

Fig. 6.4 gives the pond layout.

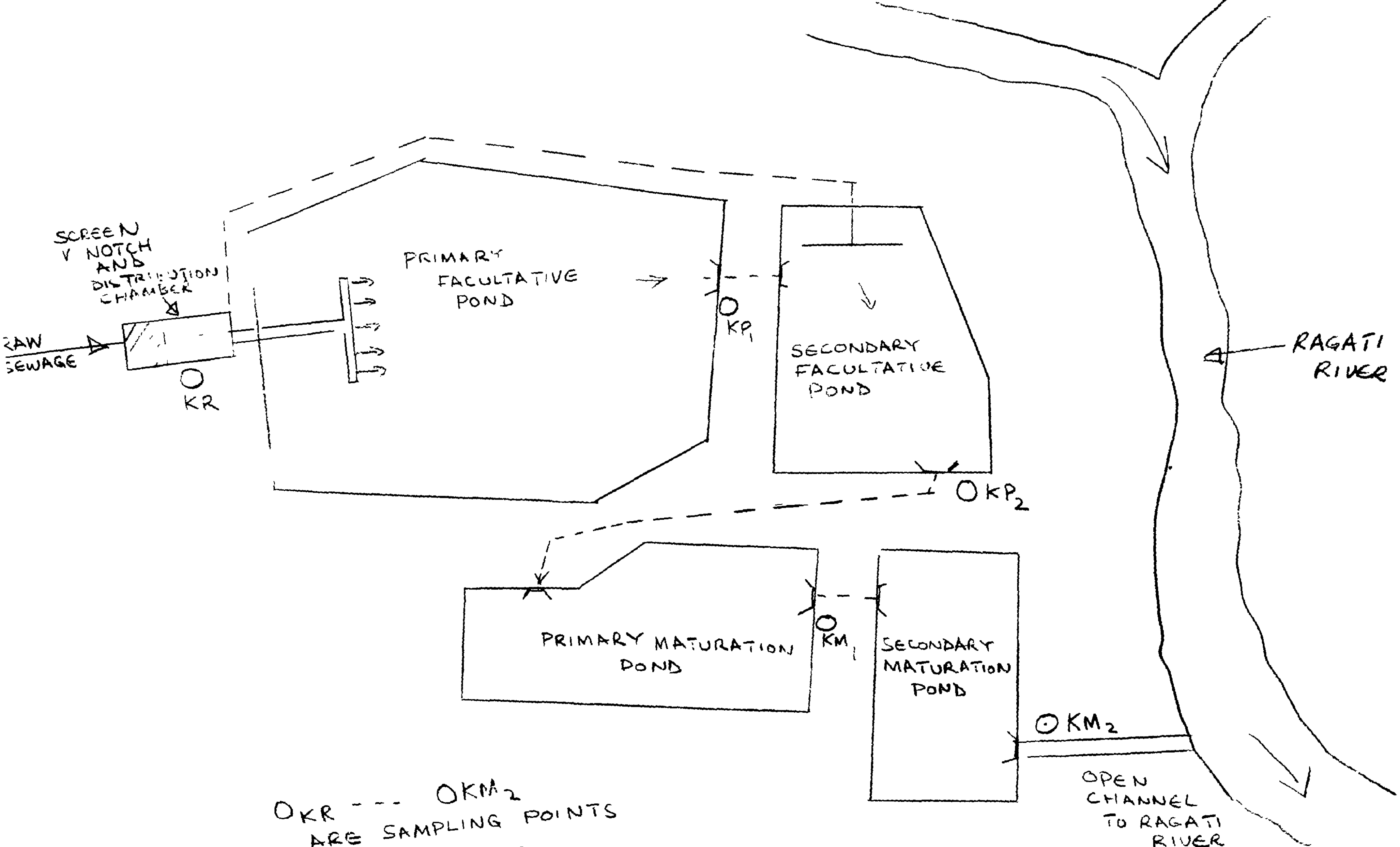


FIG. 6.4 KARATINA WSP LAYOUT

7. RESULTS AND DISCUSSION

The results obtained after analysis of samples paints a dismal picture.

The strength of the raw sewage received by the W.SP. is above 550 mg/l. This, coupled with apparent overloading and inflexibility of their operation points to problems in achieving the desired goals at 20/30 mg/l (BOD_5/suspended solids) and high coliform removal as is expected with WSP. The results obtained show that there is room for improvement and it is even necessary to improve or build extra ponds at some of the sites under consideration.

Before starting regular analysis of the selected W.S. Ponds, a lot of problems were encountered. The biggest problem was organisation especially how to get the necessary reagents. It took almost 4 months (from September 1983 to December 1983) to get the chemicals from Germany. This means that the study period was shortened by 4 months since it was supposed to end by end of February 1984, being of 6 months duration.

Permission to visit and sample some of the W.S.P. took so long especially Dandora, the Nairobi City Commission took almost 3 months to grant permission and lay conditions necessary.

Owing to the long distances especially to Embu/ Karatina (almost 400 kms.) it was necessary to use an ice box and the time taken to bring the samples to the laboratory was almost eight hours. This means that the samples could not be analysed the same day.

The volume of work to be done in the analysis was quite big (8 samples for Karatima/Embu) and 5 for Dandora. Out of these samples, the following parameters had to be obtained, suspended solids, pH, Eschericia coli, Biochemical Oxygen Demand and Chemical Oxygen Demand. Due to the 5 working days/week, care had to be taken so that the 48 hr. E Coli count, the BOD_5 tests did not fall on Saturday or Sunday or on a public holiday since the laboratory remains closed on these days.

In addition, some samples especially for E Coli gave no count and this could possibly be attributed to the sample bottles being contaminated. Some other results of BOD_5 and C.O.D. were suspect and these could be attributed to human error and probably **due to the state of** some of the reagents. For BOD_5, the starch indicator didn't give clear colour changes sometimes.

Nevertheless, the following results were obtained.

Where there is astericks *, it means that the results were suspect. **It should be noted that all samples analysed were grab samples.**

Table 7.1

TABULATION OF RESULTS

EMBU

DATE OF SAMPLING	WHERE SAMPLED	pH	CHEMICAL OXYGEN BEMAND (COD) mg/l	BIOCHEMICAL OXYGEN DEMAND (BOD_5) mg/l	SUSPENDED SOLIDS S.S mg/l	E COLI per 100mL
	ER	7.6	1408	ERROR IN	350	-
7/2/84	EP	7.9	1152	DILUTIONS	280	4x10^{7}
	EM	8.0	400		100	3.7x10^{5}
16/2/84	ER	7.5	1600	1307	745	NO COUNT
	EP	7.8	368*	423*	195	8.9x10^{5}
	EM	8.0	272*	350*	115	7x10^{4}
6/3/84	ER	8.2	1328	743	505	1.75x10^{7}
	EP	8.5	576	243	275	4.9x10^{5}
	EM	8.4	176	223	125	1.04x10^{6}
	ER	7.1	1408	660	770	4.9x10^{6}
13/3/84	EP	7.4	1152	310	475	2.2x10^{4}
	EM	7.4	400	240	125	1x10^{4}

ER = Embu Raw waste water   EP = Embu Pond effluent   EM = Embu Maturation pond effluent

All samples carried out on grab samples

Table 7.2

KARATINA

DATE OF SAMPLING	WHERE SAMPLED	pH	CHEMICAL OXYGEN DEMAND (COD) mg/l	BIOCHEMICAL OXYGEN DEMAND (BOD_5) mg/l	SUSPENDED SOLIDS S.S mg/l	E COLI per 100ml
2/2/84	KR	7.4	1080	548	339	
	KP_1		808	172	296	
	KP_2		448	180	227	
	KM_1		352	145	147	
	KM_2	8.2	304	130	111	
7/2/84	KR	7.5	1600	ERROR IN DILUTION	360	$5.6x10^{6}$
	KP_1	7.8	960		210	$1.7x10^{6}$
	KP_2	8.4	920		270	$1.4x10^{6}$
	KM_1	8.5	520		70	$1.2x10^{5}$
	KM_2	8.0	1400*		20	$4.0x10^{4}$
16/2/84	KR	7.0	1080	960	650	$4.1x10^{7}$
	KP_1	7.5	640	443	160	$2.3x10^{6}$
	KP_2	7.8	272	373	190	$8x10^{4}$
	KM_1	8.1	416	473	180	-
	KM_2	7.8	418	333	145	$3x10^{4}$
6/3/84	KR	7.9	1136	577	395	$3.6x10^{7}$
	KP_1	8.7	736	163	390	$1.7x10^{6}$
	KP_2	8.6	720	85	380	$5x10^{5}$
	KM_1	9.0	384	50	145	$1x10^{4}$
	KM_2	8.4	448	263	180	-

Karatina contd.

Table 7.2 Karatina contd.

13/3/84	KR	7.0	1456	837	540	1.6×10^7
	KP_1	7.9	912	267	475	1.1×10^6
	KP_2	7.9	32	353	355	2×10^5
	KM_1	7.3	1184	560	510	1×10^4
	KM_2	7.5	560	395	225	-

KR = Raw sewage at inlet

KP_1 = Karatina primary facultative pond effluent

KP_2 = Karatina secondary facultative pond effluent

KM_1 = Karatina primary maturation pond effluent

KM_2 = Karatina secondary maturation pond effluent or outfall

Table 7.3

DANDORA

SAMPLED ON 22/2/84

	PH	COD	BOD_5	TS	SS	E. COLI
RAW	7.9	1080	585		555	$1.32x10^7$
FACULTATIVE POND 1 F_1	8.0	448	243		300	$3.06x10^6$
FACULTATIVE POND 2 F_2	8.2	288	175		210	$9.27x10^5$
MATURATION POND 1 M_1	8.3	416	150		135	$7.1x10^5$
MATURATION POND 2 M_2	8.5	304	115		125	$1.7x10^5$

SAMPLED ON 29/2/84

	PH	COD	BOD_5	TS	SS	E. COLI
RAW	7.2	*272	*153		175	$3.13x10^6$
FACULTATIVE POND 1 F_1	7.3	512	147		277	$1.22x10^6$
FACULTATIVE POND 2 F_2	7.5	528	157		250	$1.6x10^5$
MATURATION POND 1 M_1	7.6	512	137		225	$4.1x10^5$
MATURATION POND 2 M_2	7.7	352	78.3		125	$1.0x10^5$

SAMPLED ON 19/3/84

	PH	COD	BOD_5	TS	SS	E. COLI
RAW	8.5	720	*88.3		230	$4.63x10^6$
FACULTATIVE POND 1 F_1	8.7	576	123		290	$2.5x10^5$
FACULTATIVE POND 2 F_2	8.9	448	125		265	$1x10^5$
MATURATION POND 1 M_1	8.9	512	130		230	$1x10^4$
MATURATION POND 2 M_2	8.9	416	75		195	$1x10^4$

Table 7.4

TABULATION OF RESULTS

DANDORA

SAMPLED ON 31/1/84

	PH	COD mg/1	BOD_5 mg/1	TS	SS mg/1	E COLI per 100ml
RAW	7.2	1240	548	1176	350	-
FACULTATIVE POND F_1	7.4	240	172	584	130	$3.7x10^4$
FACULTATIVE POND F_2	7.5	160	180	408	138	$3.7x10^6$
MATURATION POND M_1	7.6	240	145	528	142	$3.3x10^5$
MATURATION POND M_2	7.9	200	130	476	78	$3.1x10^8$*

SAMPLED ON 9/2/84

	PH	COD mg/1	BOD_5 mg/1	TS	SS mg/1	E COLI per 100ml
RAW	7.1	1040	510		515	$7x10^6$
FACULTATIVE POND F_1	6.9	364	175		215	$8x10^3$
FACULTATIVE POND 2 F_2	7.2	544	137		190	$2.4x10^6$
MATURATION POND 1 KM_1	7.0	248	67		140	$6.3x10^5$
MATURATION POND 2 M_2	7.2	280	113		110	$4.1x10^5$

SAMPLED ON 14/2/84

	PH	COD mg/1	BOD_5 mg/1	TS	SS mg/1	E COLI per 100ml
RAW	6.6	*160	188		135	$5.5x10^6$
FACULTATIVE POND 1 F_1	6.9	320	120		215	$2.9x10^6$
FACULTATIVE POND 2 F_2	7.1	368	86.68		255	$7.4x10^5$
MATURATION POND 1 M_1	7.2	288	75		160	$5.5x10^5$
MATURATION POND 2 M_2	7.3	368	75			$4.9x10^5$

Table 7.5

% Reductions in BOD_5 COD, E COLI and S.S.
For Dandora W.S.P.

REDUCTION PERCENT (%)

DATE	31/1/84	9/2/84	14/2/84	22/2/84	29/2/84	19/3/84	Ave % REDUCTION
BOD	76.3	77.8	60.1	80.3	48.8*	87.1	75.7
COD	99.8	73.1	-	71.9	33*	-	81.4
E Coli		941	91.1	98.7	96.8	99.8	96.1
S.S.	77.7	78.6	-	77.5	28*		

PERCENT REDUCTION IN BOD_5, COD, E COLI and S.S.
For Karatina W.S.P.

REDUCTION PERCENT (%)

DATE	2/2/84	7/2/84	16/2/84	6/3/84	13/3/84	AVERAGE %
BOD	76.3	-	65.3	54.4	52.8	62.2
COD	-	12.5*	61.3	60.6	61.5	61.1
E Coli		99.3	99.9	99.97	99.93	99.77
S.S.	-	94.4	77.7	54.4	58.3	71.2

PERCENT REDUCTION IN BOD_5, COD, E COLI and S.S.
for Embu W.S.P.

REDUCTION (%)

DATE	2/2/84	7/2/84	16/2/84	6/3/84	13/3/84	AVERAGE
BOD	-	-	73.2	70.0	63.6	68.9
COD	-	76.9	83.0	86.7	71.6	79.6
E Coli		98.76	99.74	94.05	99.80	98.1
S.S.	-	71.4	84.6	75.2	83.8	78.8

7.1 Karatina W.S.P.

Over the study period these ponds did not perform as well as expected and they did not fulfil the 20/30 mg/l BOD_5/SS standards. However the percent reduction in BOD_5 over the 2½ months study period averaged 62.2%. From the results it is apparent that from late December to middle of March, there is a decrease in percent reduction in BOD_5. Perhaps this has got a connection with observations made on 3rd March 1984 when the primary maturation pond (KM_1) had turned slightly brown especially at its inlet. The following week on 13th March, 1984 it was noticed that the secondary facultative pond KP_2, the primary maturation pond KM_1 and the final maturation pond KM_2 had turned slightly pink and especially so at the banks and corners. It was also observed that the pink colour was predominant where scum and floating sludge mats had collected.

In the pond KP_2, it was also observed that the polythene used to line the bottom of pond had started floating to the surface. This could mean that there is some leakage. During the study period, the effluent was just a trickle and this did not compare with the influent raw sewage. Since the study time concided with the hot dry season, it can be assumed that the seepage and evaporation took a sizeable volume of pond water.

During this period, there was vigorous algae growth and this can probably account for the high BOD_5 values obtained since the samples were unfiltered.

The pink colour could have been caused by growth of coloured micro organisms if sulphide or sulphate concentration was high. Generally such micro organisms are associated with waste waters that contain excess hydrogen sulphide (Gloyna 1971). Note that from the tabulated results of 6th March the pH of KM_1 reached 9.

Fig. 7.1 showing Karatina inlet to primary facultative pond - Note: the scum at bottom of picture

In the primary facultative pond KP_1 there was a lot of scum and despite the efforts of the two pond attendants to disperse it they still kept on reappearing.

The E Coli count results obtained showed that the effluent from W.S.P. was quite high although an average reduction figure of 99.77% was obtained over the period. This does not compare with $5x10^3$. FC/100ml From a study carried out in 1977 and 1978 (Bozniak 1978) around January to March 1978 it is clear that the 1984 results for the same period is worse. The BOD and COD influent is higher today than 1978 and consequently so are the effluents. See Table 7.6a and 7.6b for comparison. This could probably indicate that the pond effluents content of algae is too high.

Table 7.6 a BOD, COD suspended solid results for Jan. Feb. March (Bozniak 1978) All results are in mg/l

MONTH	PARAMETERS	RAW SEWAGE	PRIMARY	SECONDARY	TER-TIARY	MATURAT.
JAN.	B.O.D.	315	35	20	24	17
	C.O.D.	195	133	105	97	89
	S.S.	-	-	-	-	-
FEB.	B.O.D.	-	-	-	-	-
	C.O.D.	353	298	129	98	129
	S.S.	-	-	-	-	-
MAR.	B.O.D.	353	78	59	57	26
	C.O.D.	578	204	165	286	167
	S.S.	-	-	-	-	-

Table 7.6b Showing results obtained from Karatina W.S.P.
All results in mg/l

		KR RAW SEWAGE	KP_1 PRIMARY FACULTATIVE	KP_2 SECONDARY FACULTATIVE	KM_1 PRIMARY MATURATION	KM_2 SECONDARY MATURATION
2/2/84	BOD mg/l	548	172	180	145	130
	COD	1080	808	448	353	304
	SS	339	296	227	147	111
7/2/84	BOD	-	-	-	-	-
	COD	1600	960	920	520	1400*
	SS	360	210	270	70	20
16/2/84	BOD	960	443	373	473	333
	COD	1080	640	272	416	418
	SS	650	160	190	180	145
	BOD	577	163	85	50	263
	COD	1136	736	720	384	448
	SS	295	390	380	145	180
13/3/84	BOD	837	267	353	560	395
	COD	1456	912	32	1184*	560*
	SS	540	475	355	510	225

7.2 Embu W.S.P.

At the start of the study period in January 1984, the primary pond had just started filling up after desludging. However it was observed that there was a dense growth of algae. Lots of scum had collected at the inlet and the pond attendants were kept busy removing the floating scum. Though the pond surrounding are well taken care of it is important that records for flow measurements, pH and regular analysis should be kept. The results obtained from analysis show that on the average BOD_5 reduction is about 70% with effluent BOD_5 values averaging 271 mg/l.

Suspended solids (S.S.) of effluent averaged 116.3mg/l.

Clearly this does not meet the effluent standards of 20/30 mg/l BOD_5/S.S. and it fails terribly.

E. Coli reduction is roughly 98% which is quite high although the E Coli count of 3.73×10^5 EC/100 ml does not compare favourably with the required standard of 5×10^3 FC/100 ml.

From studies carried out by (COWI consult 1983) it appears that the COD and BOD of influent and effluent is far much higher today than at the time of the COWI consult study.

Probably, the reason why such results were obtained is because the pond community has not stabilized since desludging was done recently.

For the time being, the W.S.P. attendants should be provided with better tools to remove the scum and probably a boat or raft to make their work easier on the pond.

Table 7.7A Analysis of composite samples of influent and effluent from first pond (COWI consult 1983)

	Influent mg/1	Effluent mg/1	Removal %
BOD_5	393	61	84
COD	619	147	76
Suspended solids	351	52	85
Free and saline Ammonia as (N)	53	38	28
Albuminoid Ammonia as (N)	11	3	73
Phosphate as (PO_4)	11.3	0.1	99

Table 7.7B Coliforms in effluent from first pond and in Rupingazi River (COWI consult 1983)

	Coliforms/100 ml	Faecal coliforms/100 ml
EFFLUENT 5 p.m.	3.1×10^6	1.2×10^6
EFFLUENT 8 a.m.	1.4×10^7	2.6×10^6
RIVER 9 a.m.	1.7×10^4	3.0×10^2

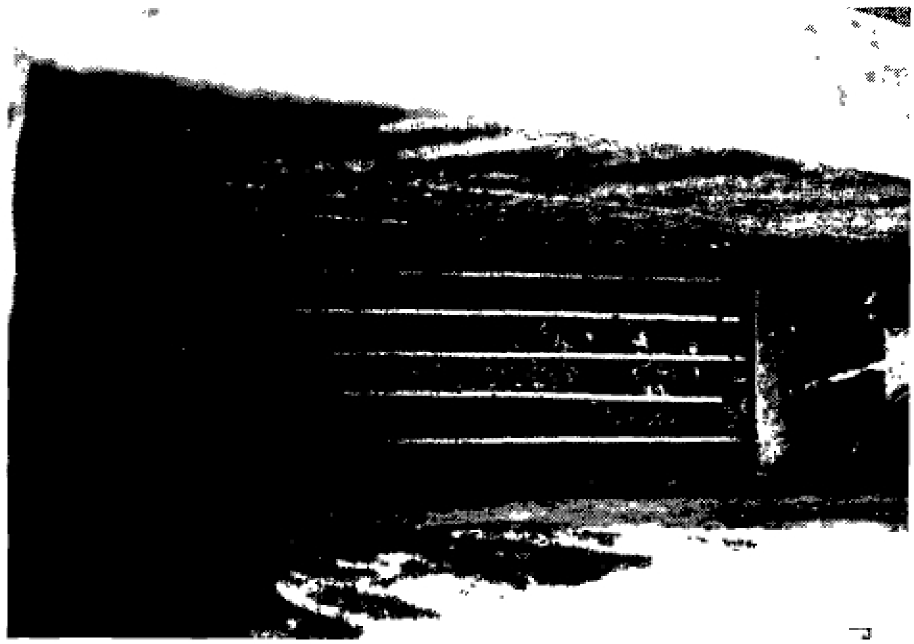


Fig. 7.2 showing coarse screens at Embu

Fig. 7.3 showing scum baffle and scum which has accumulated at the inlet of primary pond

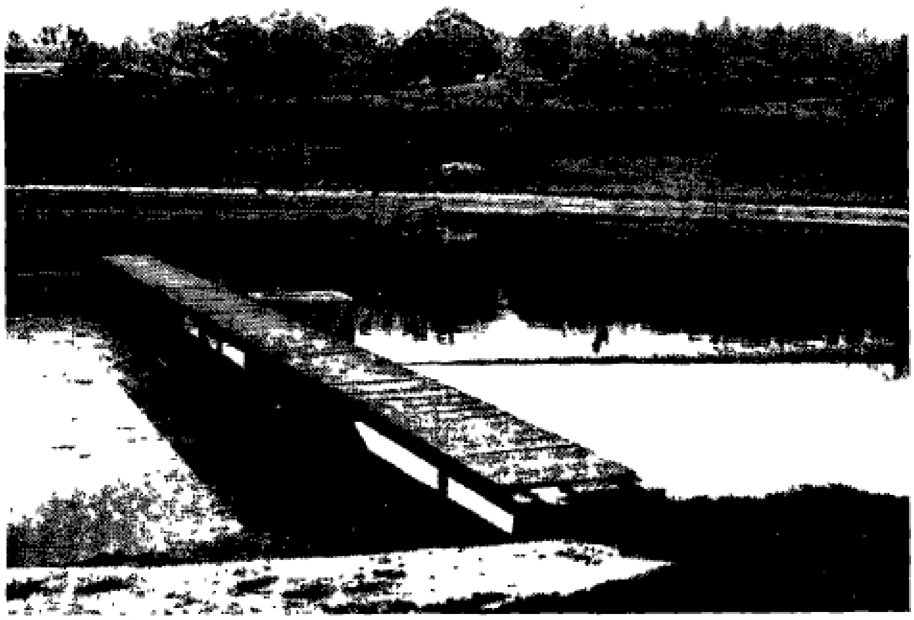


Fig. 7.4 shows submerged inlet pipe and scum baffle at Embu Primary pond

Fig. 7.5 workmen removing scum using dippers at Embu

Fig. 7.6 Maturation pond at Embu

Fig. 7.7 Maturation pond outlet
Note that flow is just a trickle

7.3 Dandora W.S. Ponds

The Dandora ponds proved to be the biggest problem during the study period. The problem arose because out of the 8 ponds existing, 4 ponds in series were selected. This was due to the fact that, of the two parallel lines, Line A which has 4 ponds was out of function due to remedial works on the last two ponds, therefore Line B was selected but the problem arose when the last two ponds on Line A started filling up. It is not clear what effect this had on Line B which was being studies. See Fig. 7.3 for the pond layout.

At the beginning, the 2 facultative ponds on Line A were discharging into the 2 facultative ponds on Line B. Later on the two parallel lines started operating independently.

From the results obtained it is quite clear that the ponds are grossly overloaded and they can not meet the 20/30mg/l BOD_5/COD effluent standards.

On the average BOD_5 reduction was about 76% while suspended solids was 77%. The figures are as follows: BOD_5 average 97.7 mg/l, COD average 320mg/l. When the raw sewage BOD_5 and COD values are compared with the design figure it is quite clear that the W.S.P. are not working properly.

Design BOD_5 = 340 mg/l
" Suspended Solids = 360 mg/l

Actual BOD_5 Load average = 547 mg/l
" Suspended solids average = 327 mg/l

The E Coli reduction was obtained as 96.1% and not as high as expected and the E Coli count of effluent was $2.36x10^5$ EC/100ml on the average and this does not compare favourably with the standard requirement of 5.10^3 FC/100ml. It was observed that there was dense mats of floating sludge and scum at the inlet of DF_1 (Primary Facultative pond) and there seems to be short circuiting along the length of ponds. Nobody seems to think of breaking these sludge mats and they are very adorous. There is a boat that could be used to help break this mats. The automatic screening machines at the raw waste water inlet are always breaking down and the maintenance crew is having a hard time repairing them.

Otherwise the plant is well taken care of and the embankments and paving slabs are all in place. The grass is cut short. However there is a lot of foaming at the outfall and this is especially so in the morning hours up to 10.00 hrs. Generally, the colour of pond contents is green and becomes progressively lighter towards the final maturation pond.

There is some wildlife in the pond which include ducks, stocks and most of all a herd of about 10 hippos seem to enjoy the surroundings. See Fig. 4 Some people come to bird watch here and this could become risky as the Nairobi City Commission is not responsible for their actions in case of accidents.

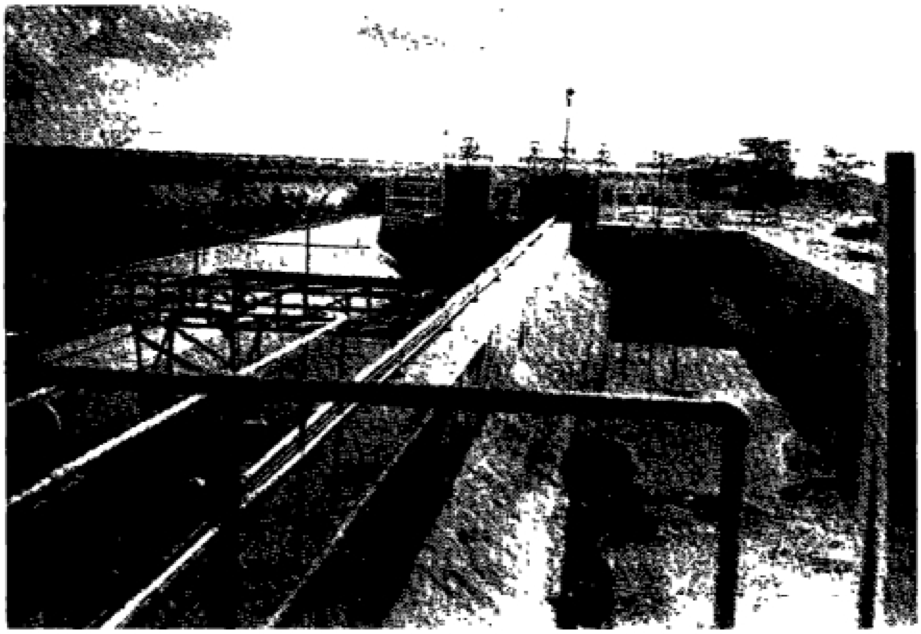


Fig. 7.8 Inlet works at Dandora W.S.P.

Fig. 7.9 showing embankment between the two parallel lines A and B.

Fig. 7.10 A hippo having a nice time in the primary maturation pond at Dandora

Fig. 7.11 shows ducks and stocks that inhabit the maturation ponds at Dandora

Fig. 7.17 Outlet structure on final maturation pond at the line A before it filled up after remedial work was done. Note the paving slabs are in place.

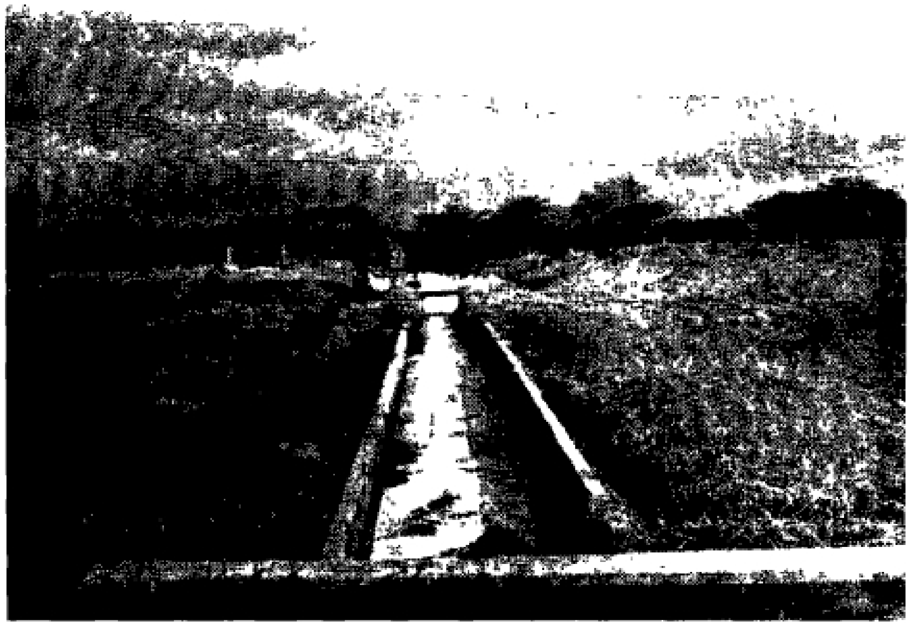


Fig. 7.13 shows outfall from final maturation pond on line B

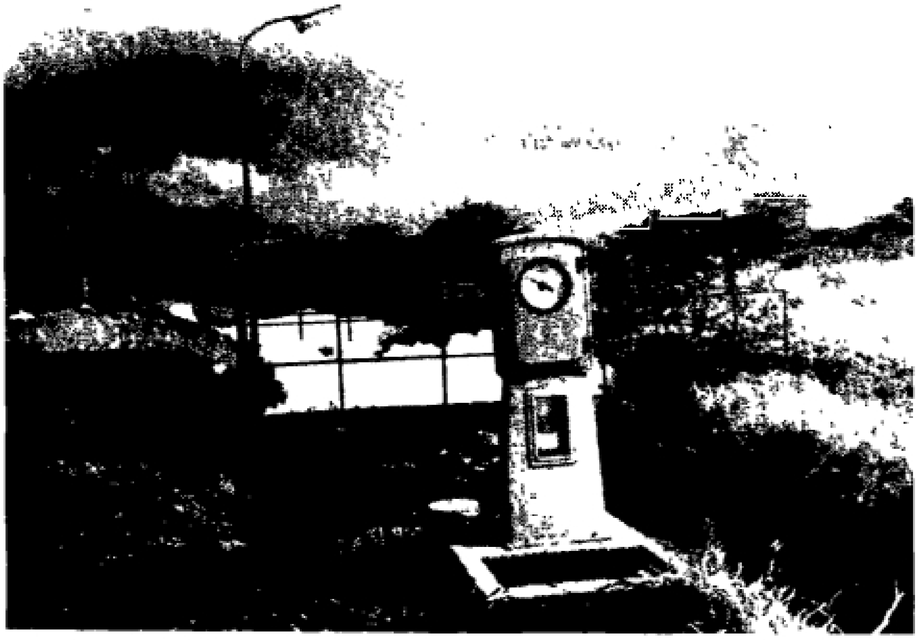


Fig. 7.14 Gauge measuring effluent from final maturation pond on line B. Note the frothing that occurs

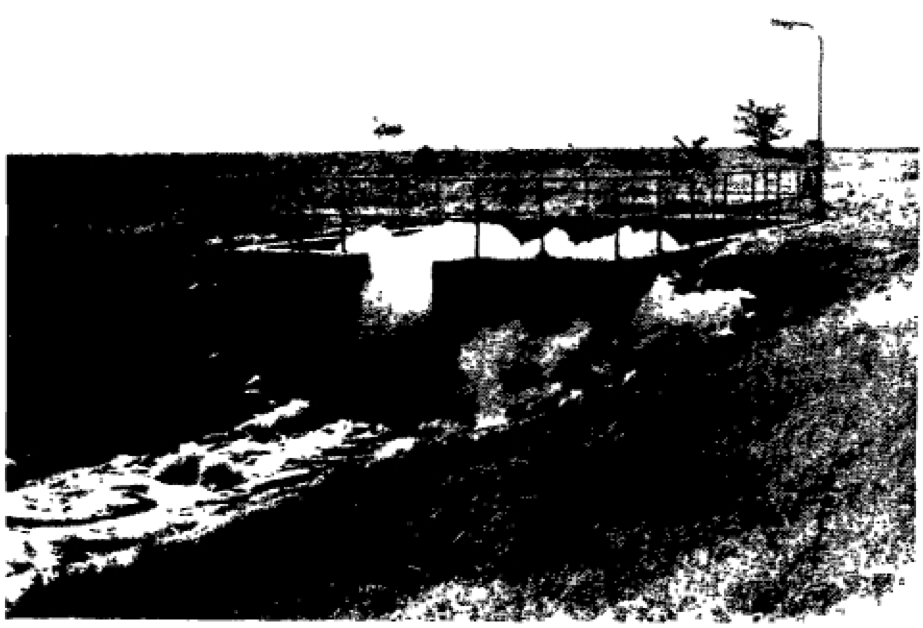


Fig. 7.15 Outfall to river showing the frothing

8. CONCLUSIONS AND RECOMMENDATIONS

To conclude about the results, it is very difficult since the available analysis results are so few. Generally, to evaluate how well the W.S.P. are working, the following points have been raised as regards design criteria, 20 mg/l S.S. recommendations, question of algae being discharged with WSP effluents, whether the high BOD_5 COD, S.S. have a bearing on the evaporation and seepage, etc.

8.1 Design Criteria

The current design criteria as stipulated in (Report No. 9 WHO 1973) should be evaluated with results obtained from the existing W.S.P. This is very important especially when the question of 20 mg/l of S. Solids is raised.

The algae that flows out with the effluent of WSP can be quite high in some cases and as far as WSP effluent is concerned, it appears that 20 mg/l S.S. is not realistic. This is so when one considers the nature of algae. Retention times should be checked since short circuiting probably occurs in most ponds.

8.2 Algae and WSP effluent

The algae that is discharged with the W.S.P. effluent will exert a delayed BOD_5 value. This is because the algae is on organic material. To ascertain the true or more realistic value of BOD_5 of W.S.P., the samples should be filtered which was not done in this study.

8.3 High BOD_5 COD and S.S. values

Since temperatures are high in the study areas, the question of evaporation and seepage should be looked into. Is there any relationship beteen the high BOD_5, COD, S.S. and the evaporation? If so what is the extent of this relationship?

8.4 Total Kg BOD_5/day removal

To know how W.S.P. are functioning it would be better to evaluate the total Kg BOD_5/day removal and to get this, the flows of raw waste water entering the WSP and the effluent should be measured. By comparing the BOD_5 of influent and effluent, a realistic figure can be obtained for total BOD_5 removal in Kg/day.

8.5 Need for further research

Considering how short the study period was, it is felt that there is need for further research. This research should cover the topics mentioned in 8.1 ----- 8.4.

In addition, the sampling should be done at various levels at the pond outlets to see whether E Coli counts will vary with depth of sampling.

Such measurements like flows in and out of W.S.P., pH, temperatures and weather conditions should be noted daily. This is to help in monitoring the WSP performances.

The following page gives suggestions and recommendations on how to improve the performances of W.S.P. For the recommendations to be meaningful, the responsibilities of Local Authorities (owners) and plant operators have been defined.

8.6 SUGGESTIONS AND RECOMMENDATIONS

The operation of W.S.P. is the responsibility of the local authority as well as the operator. Between these two - each has a set of responsibilities and colletively, the fulfilment of these responsibilities means proper operation of the W.S.P.

8.6.1 Owners Responsibility

It should be the responsibility of the owner (local authority) to:

- have a trained conscientious operator who is capable of operating the installation.
- Provide a trained competent maintenance crew to back the operator
- provide the necessary tools, material and parts needed for proper plant operation and maintenance
- Provide proper instructions and orientation to to the operation/maintenance crew
- Provide opportunities for plant personnel to increase their knowledge by their participation at meetings and special

training courses. This will give the personnel a sence of importance in knowing that their work is appreciated . This gives them personal satisfaction on top of their monetary benefits.

- Provide salary/emoluments that are commensurable with the responsibility. Quite often the salaries paid to most operators is not what would be expected considering the importance of the W.S.P. and the amount of money used to construct them.
- Laboratory facilities for control and assessment of their own performance.

8.6.2 Operators Responsibility

The operator is responsible for:

- the efficient and proper operation of W.S.P. to meet the effluent qualities stipulated by the standards.

- Maintaining equipment, building and grounds.

- Maintaining a safe healthy environment

- Performing or having tests performed and making observations for the proper operation of W.S.P.

- properly interpreting and applying laboratory analysis results.
- Notifying the local authority far enough in advance so that tools, parts and supplies will be available when needed.
- Keeping records
- Write reports to senior personnel

8.6.3. W.S.P. Operation and Performance

Ponds can be operated in parallel or in series. Fig 8 shows ponds in parrells operation. In parallel operation the influent waste water is discharged in equal amounts to all the primary ponds . This is used to distribute excessively high loads to all cells.

In series operation the waste water is discharged to the first pond and then after treatment it flows into the second pond, to the third pond. Each pond provides additional treatment.

The quality of the effluent from W.S.P. depends to a large extent upon the amount of algae in the effluent. Algae is normally less in the secondary pond than in the primary.

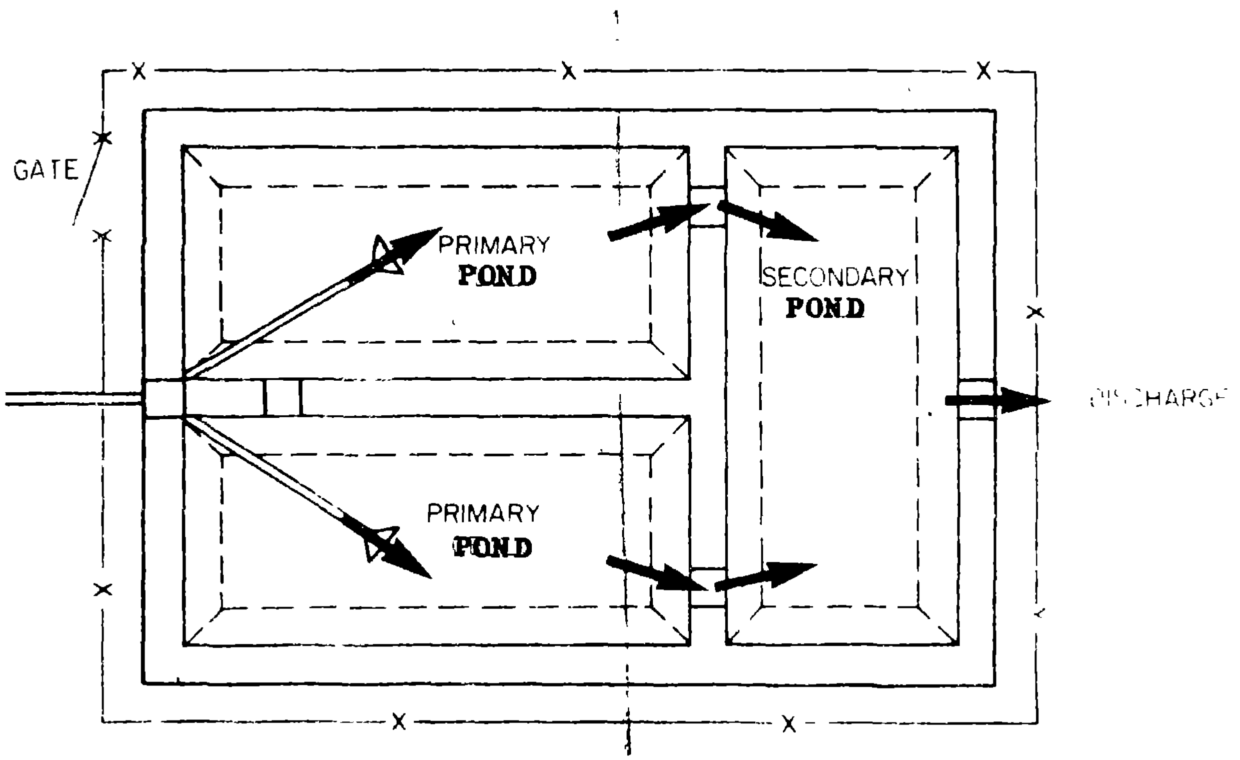


Fig. 8.1

Ponds can be operated in PARALLEL or in SERIES. The following diagram shows ponds in parallel operation

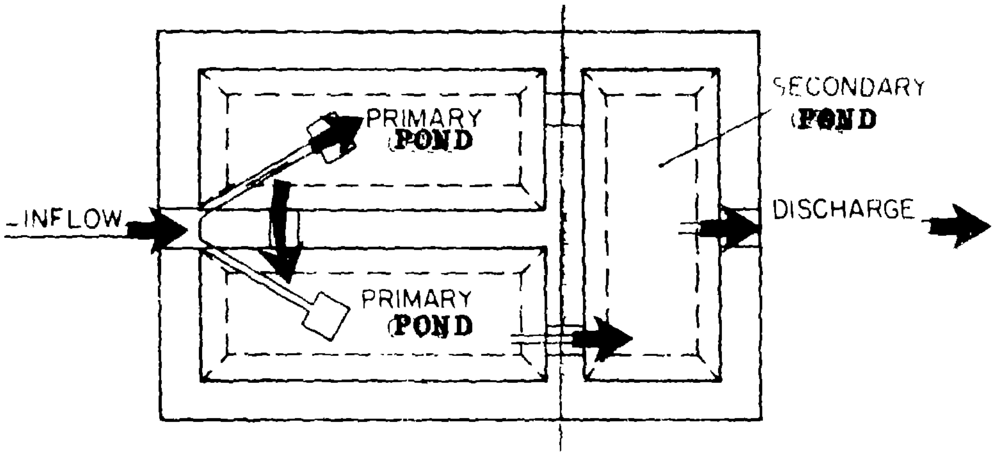


Fig. 8.2 Diagram shows ponds in series

8.6.4 How to determine whether W.S.P. are working properly

Laboratory tests are important but an Operator can also determine pond efficiency by observing waste water colour, odour, vegetation growth and formation of scum mats.

8.6.4.1 Colour: A properly functioning facultative pond with a dark sparkling green colour. This is mainly caused by the large amount of growing algae. Since there is less algae in the secondary pond it will be clearer . If the colour changes to a dull green or yellow problems are developing. The PH and DO (Dissolved Oxygen) are dropping and blue green algae are becoming predominant. When the colour in the ponds changes to grey, dark green or even black, there is a problem and anaerobic conditions have turned the pond septic.

A brown colour creates no problem when it is a result of certain types of algae. However, this is not good if it is due to silt or bank erosion. (WPCF)

In summary the colour in a pond indicates to the operator the following conditions:

Dark sparkling green	- good; high pH and DO
Dull green to yellow	- not so good, pH and DO are dropping; blue green algae are becoming established
Grey to Black	- very bad, pond is anaerobic
Tan to brown	- OK if caused by type of algae bloom - Not good if due to silt or bank erosion.
Red or pink	- presence of purple sulphur bacteria (anaerobic conditions) or red algae (aerobic conditions). This could be occasioned by the development of coloured micro organisms especially in facultative ponds during the hot season if sulphide or sulphate concentration

is high. Their presence indicate prior overloading stratification or operational deficiency (Gloyna 1971)

8.6.4.2 Sludge mats

Significant deposits will occur if the pond is heavily loaded. Another common reason for accumulation of deposits is storm water. Storm water enters the sewers and therefore the pond. The sand and silt in the storm water tends to settle very quickly near the inlet pipe and there is a sludge build up and the following signs may be observed.

- excess solids carrying over to secondary pond.
- thick sludge cover
- sludge mats

If solids settle near the inlet pipes, these solids should be removed by pumping to the shore.

To prevent sand and grit build up near the inlet pipe.

- grit chambers should be installed
- repair broken sewers
- ensure adequate distribution of influent

8.6.4.3 Organic overloading

To determine pond loading it is necessary to know the average daily flow and the BOD_5 of the raw waste water. A composite sample taken over a period of 24 hours given a representative sample.

Using the average flow and the average BOD_5 value taken over a period of several weeks, the loading can be calculated as follows:

$$\text{loading Kg/ha/day} = \frac{\text{Flow} \times BOD_5}{1000 \times \text{area}}$$

where

Flow is in m^3/day

BOD_5 is in mg/l

Area is in hectares

Comparing the results obtained with the design loading should show whether pond is overloaded or not. In Kenya a commonly used figure is 225 kg BOD_5/ha/day.

(Fraser 1973)

In some instances an otherwise normally operating pond suddenly turns septic or anaerobic. This condition becomes even more critical if pond is overloaded. The reason for it is the following.

The biological cycle in the pond may generate just enough dissolved oxygen for the days need.

But during the hours of darkness, when the algae do not have the sunlight necessary for growth, and oxygen production, the bacteria continue to use oxygen. Consequently, there is a sharp decline in oxygen production. For an already overloaded pond, this may be enough to turn the pond anaerobic overnight.

Possible solutions to organic overloading are

- convert flow pattern series to parallel operation
- Install aeration equipment
- add more ponds.

<u>Note</u> The organic overloading is normally caused by increased population and by increased volume of industrial load

- installation of aeration equipment is an expensive short term solutions.

8.6.4.4 <u>Hydraulic overloading</u>

Hydraulic overloading may be caused by increased volume of waste water due to increased population or by increased volume of industrial wastes. Other causes include storm water inflow and infiltration.

Hydraulic overloading reduces the detention times in the ponds.

The following could offer possible solutions to reduce waste water flows

- locate and remove illegal surface water connections
- repair any broken sewer lines

To reduce water usage and thereby the waste water flow

- increase cost of water
- install meter to discourage wastage
- encourage industries to recycle water where possible

To be able to operate pond properly, the daily waste water flow should be measured. Flow measuring devices in common use include

- Parshall flume, V-notch or rectangular weirs
- recorders used in conjuction with flumes and weirs and provide a continous record of flows on a chart.

To calculate flows, the method is shown in Appendix 3

8.6.4.5 Periodic Samples

If possible samples of the effluent are taken weekly and the following analysis performed.

- BOD_5
- SS (suspended solids)
- feacal coliform, (E. coli)
- effluent dissolved oxygen

The samples should be refrigerated or packed in a cool box with ice and transported to the laboratory as soon as possible. Waste water samples for E.coli tests should be collected in seperate sterilized bottles.

The feacal coliform test should be started within 6 hours after sampling. The other tests should be started within 24 hours of sampling to get accurate results.

Finally a monthly record of all laboratory analysis should be kept for future reference.

8.7 Maintenance

Proper maintenance of W.S.P. is essential for efficient treatment. To properly maintain pond system the following factors should be considered.

- odour control
- weed control
- vegetation control on the dike

- insect control
- dike maintenance
- control structure maintenance
- seepage control
- toxic material control
- vandalism

8.7.1. Odour Control

Odours may arise from a number of situations. Frequently they are associated with the decay of mats of algae that have been blown to a bank or corner. Chlamydomonas for example can grow rapidly and reduce light penetration. During hot period and in shallow depths, sludge mats rise from the bottom. These organic debris usually accumulate in corners and if not disturbed the entire mass may become covered with blue green algae.

Usually bacterial activity is intense and odours are overpowering (Gloyna 1973)

Odours can also be caused by anaerobic conditions in the pond. Basically odorous conditions can be caused by:

- extensive cloud cover which reduces the amount of sunlight and therefore the amount of dissolved oxygen

Fig. 8.4 Dispersal by floating mats by water jet (Gloyna 1971)

8.7.2 Weed Control

Plants around or in the ponds cause problems. Plants that grow to the surface promote concentration of scum and sludge mats and encourage insect breeding.

Surface weeds which float on the waste water surface poses a threat when they die. They cause a high oxygen demand.

Control of surface weeds

- introduce ducks which eats the weed
- clear the area around the ponds to provide a good fetch distance 100m all round is quite good.

- toxic waste that kills a portion or all the bacteria
- a sudden shock load of high strength organic wastes.

The solution to the sludge mat problem is immediate dispersal. Agitation of surface causes the floating mass to break up and settle to pond bottom. This can be achieved by use of a water jet from a hose.

Alternatively a foot powered raft or engine powered paddle wheel can be used to agitate the surface. See fig 8.3. and 8.4.

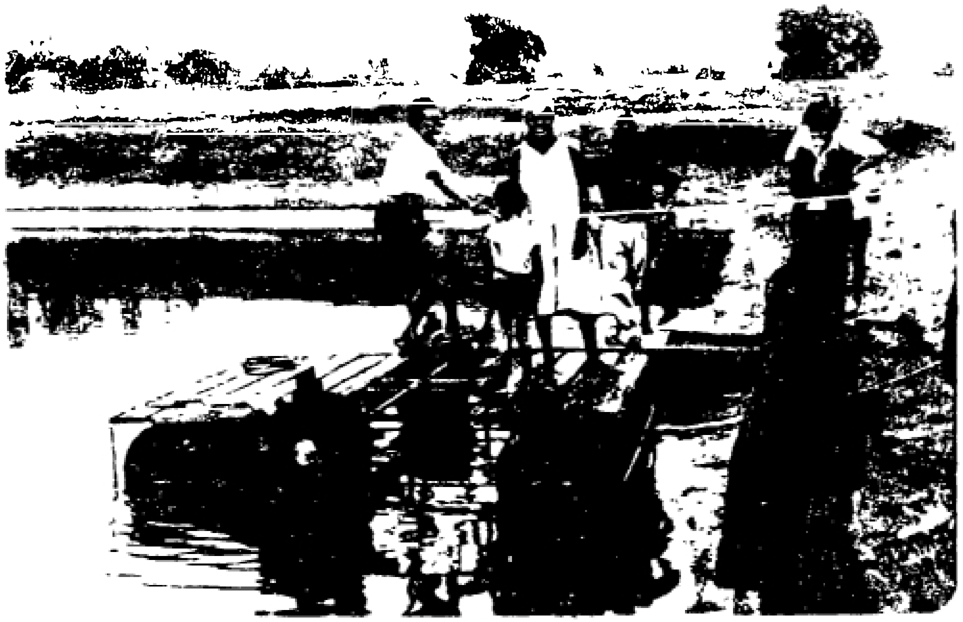


Fig. 8.3 Dispersal by means of Paddle wheel (O. Faurby 1982)

This causes mixing and some of these weeds can not flourish under these conditions .

8.7.3. Vegetation control on the dike

Dikes have a protective grass cover. The embarkments should be inspected regularly for erosion due to wind. Paving slabs should be inspected to see whether they are sliding off as wind and wave action would cause erosion of embankments. The grass cover on the dike must be cut short always. Burrowing animals like moles should also be checked for and exterminated as their action can weaken the dike.

8.7.4. Insect Control

The most common insects creating problem around W.S.P. are mosquitoes. A poorly maintained pond with lots of growing rooted plants or scum provides and ideal breeding site for mosquitoes. Regular clearing of vegetation and of scum from pond end is necessary to control insects.

8.7.5. Control Structures

Leakage and corrosion are the main cause that affect control structures.

To reduce corrosion lubrication of gates and valves is vital. To stop leaks gaskets should be replaced.

8.7.6. Control of Toxic Material

Problem of toxic material in the influent cannot be solved in the pond itself. Any industrial wastes or any other discharges to the sewage are best controlled by elemination at their source. Therefore it is important to know which industrial plant may be discharging toxic wastes and maintain good communication with them.

8.7.7. Vandalism

This can be reduced by

- installing lighting
- enclose the structures
- install fencing around the whole area
- have regular surveillance
  e.g. watchman etc.

8.8. Safety

Safety and safety considerations are very important not only to what is done in maintaining the W.S.P. but to every other aspect of pond operation. A good operator must recognize his responsibility to himself, his family his co-workers, his community and his employer.

Basic safety rules must always be considered.

W.S.P. like other waste water treatment facilities, must be treated with caution and respect from safety and public health point of view by operators and the general public alike.

In some areas, ponds have been source of attraction to children as well as adults for recreation purposes. Incidents of fishing and swimming in W.S.P have been reported, recreational use should be discouraged and safety for many reasons.

The possibility of contamination or infection from pathogenic organisms does exist when one comes in contact with waste water in W.S.P.

Perhaps the following points should be noted:

- workers should wear proper clothing such as overalls, gumboots or wellingtons

- they should visit the doctor regularly for medical check up.

- personal hygiene around W.S.P. should be emphasized and washrooms provided with disinfectants should be available

- first aid facilities should be provided
- lifebouys should be placed at strategic places around embankments.

Although very little monitoring of W.S.P. has been carried out, general impression is that ponds are easy to construct and cheaper to operate than trickling filters as used in Kenya.

Finally, if the recommendations and suggestions given above are followed, it is possible to improve results from existing (W.S.P.) and achieve even better results from plants designed in the future. This would justify the trend in Kenya of switching from trickling filters to waste stabilization which is evident for the last ten years.

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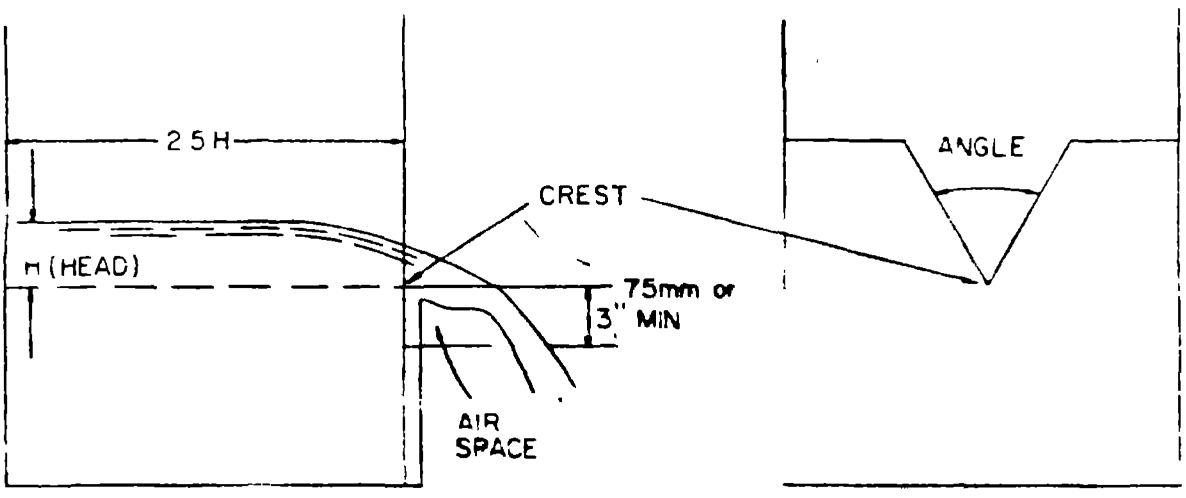
Appendix 1

Determination of flow through a V notch weir

The following information will help to determine flow through a V-notch weir



To determine flow, measure the head of water above the crest of the weir. Then use the chart on the following page to determine flow in metric units.

Determination of flow through
a V notch

DISCHARGE FROM TRIANGULAR V-NOTCH WEIRS (METRIC UNITS)

Head (H) in cm	Flow in cu m/d 90° notch	60° notch	Head (H) in cm	Flow in cu m/d 90° notch	60° notch
2.5	11.9	6.92	17.1	1,420	818
3.2	20.8	12.0	17.8	1,550	894
3.8	33.0	19.0	18.4	1,690	976
4.4	48.5	28.0	19.0	1,840	1,060
5.1	67.6	39.0	19.7	2,000	1,160
5.7	91.0	52.4	20.3	2,160	1,250
6.4	118	68.1	21.0	2,340	1,350
7.0	150	86.7	21.6	2,520	1,460
7.6	188	107	22.2	2,710	1,560
8.3	228	131	22.9	2,910	1,680
8.9	274	158	23.5	3,110	1,800
9.5	325	188	24.1	3,320	1,920
10.2	383	221	24.8	3,550	2,050
10.8	445	257	25.4	3,780	2,190
11.4	513	297	26.7	4,270	2,460
12.1	589	340	27.9	4,800	2,770
12.7	670	386	29.2	5,360	3,100
13.3	758	436	30.5	5,960	3,440
14.0	850	490	31.8	6,610	3,820
14.6	948	545	33.0	7,290	4,210
15.2	1050	610	34.3	8,010	4,620
15.9	1170	676	35.6	8,770	5,060
16.5	1290	741	36.8	9,570	5,530

Appendix 2

Table for calculation of discharge over rectangular weir with standard end contractions

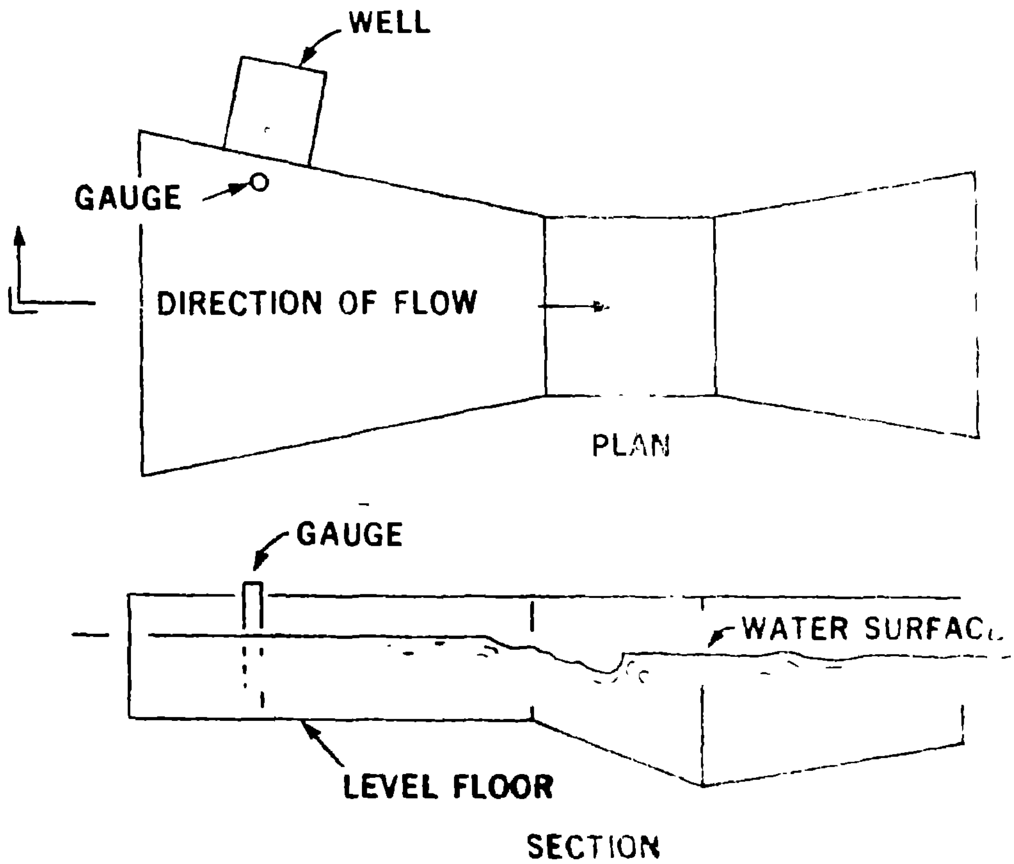
(METRIC UNITS) DISCHARGE OVER RECTANGULAR WEIR WITH STANDARD END CONTRACTIONS - CUBIC METERS PER DAY (cu m/d)

Head (H) cm	Length of weir (L) cm										
	5.1	10.2	15.2	20.3	25.4	30.5	38.1	45.7	61.0	91.4	152
0.6	5.5	11	11	16	22	27	33	38	55		
1.3	11	22	33	49	60	71	87	104	142		
1.9	22	44	65	87	104	125	158	191	251		
2.5	33	65	98	131	163	162	245	294	392	589	981
3.2		93	136	180	229	273	343	414	545	817	1,360
3.8		120	180	240	300	360	452	540	719	1,070	1,800
4.4		153	229	300	376	452	567	676	905	1,350	2,260
5.1		185	278	370	463	550	692	828	1,100	1,650	2,750
5.7			332	441	550	659	828	997	1,320	1,980	3,300
6.4			387	518	643	774	970	1,160	1,550	2,320	3,870
7.0			447	594	741	894	1,120	1,340	1,790	2,680	[illegible]
7.6			507	676	845	1,020	1,270	1,530	2,040	3,060	5,100
8.3				763	959	1,140	1,440	1,720	2,290	3,430	[illegible]
8.9				856	1,070	1,280	1,600	1,920	2,560	3,840	[illegible]
9.5				948	1,190	1,420	1,780	2,140	2,850	4,270	[illegible]
10.2				1,040	1,300	1,560	1,950	2,350	3,130	4,690	7,790
10.8					1,430	1,710	2,140	2,570	3,420	5,130	8,560
11.4					1,550	1,870	2,340	2,810	3,740	5,610	9,320
12.1					1,690	2,040	2,530	3,050	4,080	6,100	10,100
12.7					1,820	2,200	2,730	3,300	4,390	6,590	11,000
13.3						2,360	2,940	3,540	4,720	7,090	11,800
14.0						2,530	3,160	3,790	5,060	7,580	12,600
14.6						2,700	3,380	4,060	5,410	8,070	13,500
15.2						2,880	3,600	4,310	5,720	8,610	14,400
15.9							3,820	4,590	6,100	9,160	15,300
16.5							4,050	4,870	6,490	9,760	16,200
17.1							4,280	5,150	6,870	10,300	17,200

Appendix 3

Calculation of discharge over Parsahl Flume

The head over the crest of a Parshall Flume can be measured by placing a gauge stick in the sewage at the float in the flow channel or at the pipe leading to the float well and then taking a reading off the free-flow discharge chart.



METRIC UNITS

FREE FLOW DISCHARGE - PARSHALL FLUME - CUBIC METERS/DAY

Head in cm	7.6 cm	15.2 cm	22.9 cm	30.5 cm	45.7 cm
3.0	56	122	218	-	-
4.6	122	245	415	-	-
6.0	200	390	637	856	1.250
7.6	281	563	905	1,198	1,737
9.2	376	759	1,200	1,566	2,300
10.6	469	954	1,520	1,960	2,910
12.2	567	1,180	1,860	2,420	3,590
13.7	709	1,420	2,200	2,910	4,310
15.2	829	1,690	2,600	3,400	5,040
16.8	981	1,960	3,010	3,960	5,850
18.2	1,100	2,250	3,420	4,500	6,680
19.8	1,270	2,550	3,890	5,090	7,560
21.2	1,400	2,860	4,360	5,700	8,470
22.9	1,600	3,210	4,850	6,310	9,420
24.4	1,720	3,550	5,330	6,980	10,400
25.9	1,950	3,890	5,850	7,630	11,400
27.5	2,060	4,260	6,380	8,340	12.500
28.9	2,290	4,650	6,940	9,050	13,600
30.5	2,440	5,040	7,510	9,780	14,700
33.5	-	5,870	8,690	11,300	17,000
36.5	-	6,730	9,930	12,900	19,400
39.7	-	7,630	11,200	14,600	22,000