POLLUTIONAL EFFECT OF BREWERY WASTE WATER ON RUIRUAKA RIVER

BY

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DECLARATION

THIS THESIS IS MY ORIGINAL WORK AND HAS NOT BEEN PRESENTED FOR AWARD OF A DEGREE IN ANY OTHER UNIVERSITY

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ABSTRACT

The rapid rate of industrial and urban growth in Kenya with the resultant pollution of aquatic systems provided stimulus to the present study on the pollutional effects of brewery effluent on Ruiruaka river.The river, passing through the northern suburbs of the Nairobi city, offers an ideal situation of industrial pollution on a natural watercourse. Rising about 20 km west of Nairobi, it flows eastward through Limuru, Karura forest, Ruaraka (where it encounters the brewery effluent) and finally drains into the Nairobi river at the Dandora area. The pysico-chemical of a selected reach within Ruiruaka river (the Ruaraka reach) was investigated during the period 30th October 1990 to 20th February, 1991.

Temperature in the river did not seem be affected with the entry of the brewery effluent. pH values of 7.1 and 7.3 were recorded in the river before and after the brewery effluent entry respectively. Other parameters monitored before and after the brewery effluent were ; BOD_5 16 - 106 mg/l, COD 34 - 216 mg/l, DO 4.9 - 2.7 mg/l, TDS 127 - 388 mg/l and TSS 41 - 238 mg/l.

Concentrations of the organic parameters analyzed showed low levels before brewery effluent and exceedingly high levels downstream of the brewery plant, an indication of a polluting source. A generalized inverse relationship was found to exist between concentrations of parameters monitored and discharge before brewery effluent but ceased to exist after the brewery effluent discharge. This was as a result of polluting nature of the effluent.

The Streeter - Phelps DO - BOD mathematical model was tested on the Ruiruaka river

with the data collected during the study period. Calculated DO values were seen to compare with the observed DO values at a station which was 155 metres from the last effluent discharge channel. Combining the waste to discharge via one outlet made the river anaerobic at times thus making it worse than it was when receiving segregated effluent while pretreating to the proposed effluent discharge standards presented Ruiruaka river as a good source of water supply for domestic or industrial purposes.

The results of the present study will provide baseline data to reinforce the need for industries to pretreat their effluent before discharge into natural water courses.

It is concluded that the brewery plant has induced significant changes in the chemical characteristics of the Ruiruaka river and that the pollution load has caused considerable biodegradation on the river

It is therefore recommended that control at the source of pollution for the brewery plant and other polluting agents along the course and a check on the soil conservation in the cultivated areas in the river catchment will greatly improve the quality of the river water. Pollution law enforcement would help a great deal in solving this pollution problem.

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ABBREVIATIONS

BOD Biochemical Oxygen Demand

BOD_5 5 day, 20°C Biochemical Oxygen Demand

BSP Barley Syrup Plant

COD Chemical Oxygen Demand

DO Dissolved Oxygen

KBL Kenya Breweries Limited

TDS Total Dissolved Solids

TSS Total Suspended Solids

UNEP United Nations Environment Programme

WAB Water Apportionment Board

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CHAPTER 1

INTRODUCTION

In this context, the term pollutant means too much of any given contaminant such that it renders the receiving water unsuitable in the existing state for its desired best usage. Warren (1971) has concisely defined water pollution as "any impairment of the suitability of water for any of its beneficial uses, actual or potential, by man-caused changes in the quality of water".

A crucial problem facing most countries today is the acute shortage of adequate quantity and quality of water supply. This is particularly serious in most developing countries, where as a result of rapid industrialization and urbanization, the few sources of water available as well as the environment in general are constantly being exposed to pollution. Thus stream pollution control continues to be one of the principal challenges facing environmentalists in most developing countries.

Most of the industries in Kenya have given little, if any, attention to the control and management of their industrial waste water and gaseous emissions because of lax laws and the lack of strict enforcement on the existing ones (Water Act Review Draft, 1990). Moreover, for smaller industries, this has been due to lack of proper guidance from professionals in this area and several operational costs that such control would bring. The ability of a river to assimilate waste is governed by its capacity to neutralize such waste mostly by oxidation. If a river is overloaded, the system is disrupted and the oxidation capacity may be substantially reduced. Knowledge of the effects of pollution on rivers and ecosystem balance is necessary so as to determine where, when and at what rate wastes can be discharged.

Industrial waste water when discharged into water bodies result in water pollution. Such waste can be characterised by the following environmental parameters and effects: biochemical oxygen demand, suspended and dissolved solids, pH, toxicity, taste, odour, and other organic and inorganic compounds which cause the following effects on the environment.

-Sedimentation of suspended solids in the bed. Sedimented matter tend to change the nature of the bed of the water course disturbing the bottom vegetation and other aquatic life.

-Dissolved inorganic compounds usually have no specific polluting influence. A considerable change in the pH value in the water may however be detrimental to aquatic life.

-Natural water courses maintain an oxygen content sufficient to support aquatic life. The inflow of water contaminated with oxygen consuming matter tend to use up the dissolved oxygen in the water thus destroying the aquatic life.

-The dissolved substances are easily destroyed by microorganisms using oxygen dissolved in the water. The growth of the micro-organisms can lead to difficult local situations such as oxygen deficiency and formation of oxygen compounds.

The receiving water bodies are put to subsequent uses for many purposes, which include:

a. Water supply including municipal, self-supplied, industrial and domestic utilization

b. Water contact recreation of swimming, water skiing, surfing etc.

c. Non-water contact recreation including boating and river side parks.

d. Commercial fishing

e. Agricultural irrigation.

f. Navigation, etc.

There is therefore a dire need for water quality studies to establish the sources of pollution, the level of pollutants and the prediction of future sources and future levels of pollutants, (Andrew, 1972). Detailed case histories of the course of events in a stream are essential to provide some guidelines on how to restore the stream ecosystem to a better condition or perhaps to an acceptable one following severe degradation . Discharging of wastes into streams is leading to excessive nutrient enrichment in rivers, lakes, and estuaries. This accelerated process of eutrophication cause undesirable changes in aquatic life, reduces the aesthetic quality and economic value of the water body and threatens the destruction of precious water resources. This can be controlled to a great extent on the accurate identification of the sources of nutrients.

The most serious of water pollution is the threat to human health which alone makes it essential that industrial wastes be effectively treated before discharge into streams. Random disposal of Municipal and industrial discharges containing toxic chemicals or pathogens into rivers contribute largely to surface water contamination. Lead and mercury continue to be the most important of the metals of special interest with respect to their toxicological importance. Considering the wider variety of the industries established and the raw materials used, many other heavy metals can be suspected to be present in the receiving water bodies, Arsenic, Cadmium, Manganese, Chromium, etc.

However, in tropical regions, literature on the effects of pollution on streams is limited

to a few local surveys and observations. In Kenya, river pollution is now a reality. A few case studies are available to support this point, (UNEP, 1987). Some case studies aimed at determining the chemical characteristics of the water along the course of the river have also been done, (MOWD, 1976).

Monitoring work on Ruiruaka river system consist of routine water quality surveys conducted by both Nairobi City Commission and the Ministry of Water Development. The investigation involves testing water samples taken before and after the brewery effluent. In both cases, the results show heavy polluting by the said discharges.

Maintaining streams in a clean state is vital in a country like Kenya where the majority of the rural population obtain their water directly from rivers. During the history of water pollution control in Kenya, the Ministry of Water Development and other authorities who share the responsibility of water pollution control such as Local Government and the River Basin Development Authorities have depended on the Royal Commission river quality Control Standards (a BOD_5 of 20 mg/l and SS of 30 mg/l for effluent discharge into water bodies) for the purposes of controlling pollution for domestic, agricultural and industrial sources. These Standards have not been made part of the Water Act and it has therefore not been possible to use them for prosecution in courts (Water Act review draft, 1990).

Due to the rapid pace of industrial growth in Kenya, the deteriorating quality of water in rivers, streams and lakes and the absence of quality control standards which would render the relevant sections of the Water Act enforceable in law and practicable to implement, it has been necessary that the Ministry of Water Development adopts a new

standard (or rather a review of the Water Act). These reviewed standards take into account the patterns and trends in industrial growth, the technological and economic capacities of the industrial sector as well as the urgent need to conserve water resources in a state where the same can be of use in the future. (Water Act review draft 1990). Here, caution is given that the tolerance limits for industrial effluent are likely to vary from each unit depending on:-

a. The production capacity of the plant

b. The technology adopted for application in the industrial operations

c. Any other industries polluting the given river system.

d. The capacity of the receiving streams

e. The nature of the receiving system i.e land, river, estuary

f. Usage of the receiving system .

The Tusker Brewery plant at Ruaraka (located about 6 Km from Nairobi City Centre) produces about 2.25 million litres of beer daily. The raw materials used in the plant include malt, barley syrup, hops, water and yeast. All the waste water generated is discharged directly into Ruiruaka river untreated. The malting plant is situated in Nairobi's Industrial area and therefore its waste is not included in this study. The major wastewater generating activities at the Ruaraka Plant are brewing, fermentation, bottling and washing. At the time of the data collection, the waste water was being discharged via four channels into the Ruiruaka river.

It is in response to the need to maintain a clean and healthy environment that the author has had an incentive towards carrying out this study which is geared towards

ensuring that industrial development takes place in harmony with environmental protection.

The objectives of this study were to:-

1. determine the physical and chemical status of a selected reach of the Ruiruaka river
2. attempt to establish the level and extent of pollution caused by the brewery effluent in the selected reach
3. apply a mathematical model in an attempt to simulate the impacts of the waste on the river.
4. apply a mathematical model to simulate the impacts of the waste on the river if the waste was discharged untreated in a combined form through one outlet and also if some form of pretreatment of the combined wastewater was provided before discharge

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Any system of stream sanitation is dependent on natural self purification, the ability of the stream to assimilate waste and restore its own quality. Without this capacity, the World would have been buried in its own waste long ago and the water course would not be fit for any use. Given a chance to exert itself, this natural self-purification rids polluted water of microbial pollutant. However, it challenges the environmentalist to become familiar not only with the syndromes of pollution and methods of its prevention but also with the forces of natural self purification. To this end, the environmentalist must be able to:-

1. identify the origins and intensities of pollution
2. estimate or measure the magnitude of the forces of natural purification
3. recognise the limitations of these forces and
4. prescribe a regime that promises to bring about a cure either spontaneously or with external remedial aid.

However, with the increasing industrialization, urbanisation and population growth rates, the hazards of pollution and in this context, stream pollution is great. Gross pollution that seriously interferes with the beneficial uses of water resources is unnecessary, controllable and manageable by scientific, engineering and legal methods. However, complete elimination is impossible; some degree of pollution is inevitable. The degree of pollution that is acceptable depends on what we are willing to work and pay for, (Velz, 1970). This is where the drinking water standards and the

effluent discharge into water courses standards comes in. Moreover, waste disposal and pollution control are an integral part of the broader problem of the development, use and management of the total water resource.

2.1 Rational Stream Sanitation

As a gift of nature, each water course has its individual self purification capacity which to an extent differs for each type of waste. However, self purification is threefold, chemical, bacterial and organic.

Stable chemical wastes undergo little or no change in the river. The primary factor is dilution and self purification is almost wholly dependent on streamflow along the course. In a stream receiving bacterial wastes from sewage, three factors aid in self purification. Dilution takes place here as it does with chemical waters and bacteria are destroyed by the unfavourable conditions in the stream environment. The decline in the number of organisms is a function of water temperature and time; the warmer the water the higher the death rate, (Velz, 1970).

The third and most general type of waste is unstable organic matter from various sources. Here self purification is a biochemical process of decay. Oxygen dissolved in the river water is utilized in the stabilization of the organic matter which is carried out by a chain gang of biological life. The stabilization is a time temperature function and utilization of the dissolved oxygen increases as the temperature increases. Nature replenishes the depleted oxygen through reaeration though the oxygen saturation capacity of water declines as the temperature rises.

2.1.1 Biochemical Aspects Of Stream Analysis

When a polluting substance is discharged into water, a succession of changes in water quality takes place. If the pollutant is discharged into a lake in which the current about the outfall are sluggish and shift their direction with the wind, the changes occur in close proximity to each other, move their location sporadically and cause much overlap. As a result the pattern of change is not crisply distinguished. If on the other hand, the water moves steadily away from the outfall, as in a stream, the successive changes occur in different river reaches and establish a profile of pollution and natural purification so well defined that it can be subjected to mathematical analysis and generalization (Fair et. al., 1971). In most streams, this pattern is by no means static. It shifts longitudinally along the course of the stream and is modified in intensity with changes in season and hydrography. The intensity rises during the warmer months and low river stages. It is suppressed during cold seasons and when the stream is in flood. A decrease in the polluting load is similar to an increase in stream runoff.

When a single, large charge of sewage or other putrescible matter is discharged into a clean stream, the water becomes turbid, sunlight is eliminated from the depths and green algae plants, which by photosynthesis remove carbon dioxide from the water and release oxygen to it, die off. Scavenging organisms increase in number until they match the food supply. The intensity of their life activities is mirrored by the intensity of the biochemical oxygen demand. The oxygen resources of the water are drawn upon heavily. In an overloaded stream, the dissolved oxygen may become exhausted wholly, nitrogen, sulphur, carbon and other important nutritional elements run through their natural cycles and sequences of microbic population groups manage to break down the sewage matters in accordance with the nutritional requirements and

environmental adaptiveness of the constituent organisms.

Depending upon the hydrography of the stream, suspended matter is carried along with the water or removed to the bottom by sedimentation. The bottom deposits may be laid down in thicknesses varying from a thin pollutional carpet to heavy sludge banks. In the presence of oxygen dissolved in the supernatant water, benthal decomposition changes with depth of deposit from largely aerobic to anaerobic conditions. The influence of the benthal factor upon the stream varies accordingly.

The initial effect of pollution on a stream, is to degrade the physical quality of the water. As decomposition becomes active, there is a shift of chemical degradation that is biologically induced. At the same time, there is a biological degradation in terms of the variety and organisation of the living things that persist or make their appearance. In the course of time or flow, the energy values of a single charge of polluting substances are used up. The biochemical oxygen demand is then decreased in intensity and the rate of absorption of oxygen from the atmosphere, which at first has lagged behind the rate of oxygen utilization, falls into step with it and eventually overwhelms it. The water becomes clear. Green plants flourish again and release oxygen to the water by photosynthesis. Other higher aquatic organisms including game fish, which are notably intolerant to pollution, reappear and thrive as in a balanced aquarium. The stream waters are returned to normal purity.

If pollution is kept within bounds, it will contribute to the fertility of the water. The growth of useful aquatic life may thereby be promoted. Then fish will reproduce in increased numbers in the aquatic meadows that derive the elements for their growth

from the nitrogen and other fertilizing constituents of the waste matters. However, in the fertilization of water by organic pollutants, the danger of spreading disease through plant or animal foods must never be lost from sight. (Fair et. al., 1971).

2.1.2 Stream reaeration and oxygen sag analysis

In nature, clean waters are saturated with dissolved oxygen or nearly so. Normally therefore, waste matters discharged into natural waters undergo aerobic decomposition. Only when the supply of oxygen present in the solution or taken into solution, principally from the atmosphere cannot keep pace with the biochemical oxygen demand of the waste matters does the receiving water and with it the type of decomposition become anaerobic. Nature fortunately provides a mechanism of counteracting the effects of deoxygenation. This mechanism is known as reaeration, a means whereby, oxygen as well as other gaseous components of air are renewed in flowing stream water. The fact that oxygen supply is renewed in water courses is no guarantee however that sufficient amounts will therefore be available at the proper location for a specific water use. Reaeration is a rate phenomenon. The parameters which control the net effect of reaeration are vastly different, however, from those which affect deoxygenation (Nemerow, 1974).

Studies by Adeney in 1914-1919 as reported by Nemerow (1974) showed that the rate of reaeration is proportional to the oxygen saturation deficit. The greater the deficit, the greater the rate of solution of oxygen. Streeter and Phelps applied Adeney and Becher's findings to stream reaeration and developed the relationship as in equation 2.1

$$\frac{dD}{d_t} = k_1L - k_2D \qquad 2.1$$

The first (k_1L) represent the deoxygenation reaction. It increases the deficit proportional to the residual BOD (L) and the reaction (deoxygenation) rate k_1.
The second (k_2D) represent the reaeration reaction. It decreases the deficit proportional to the deficit existing D and the reaeration rate k_2. Besides being dependent upon the temperature as is k_1, also depends upon the depth, velocity and the physical characteristics of the above equation is the sag equation as shown in equation 2.2

$$D = \frac{k_1L_o}{k_2 - k_1}\left(10^{-k_1t} - 10^{-k_2t}\right) + D_o\left(10^{-k_2t}\right) \qquad 2.2$$

where

L_o and D_o are the initial BOD and oxygen deficit in the stream respectively

k_1 and k_2 are the deoxygenation and reaeation rates respectively

expressed as common logs and

D is the DO deficit at time t days.

A curve can be constructed from the combined effects of deoxygenation and reaeration which will plot the course of dissolved oxygen along a stretch in a river (see Figure 2.1). The curve is therefore very important in stream analysis.

The curve of deoxygenation will be the curve of the BOD reaction minus the rate of withdrawal of oxygen which starts at a maximum and diminishes continuously towards zero. Reaeration starts at zero rate since it is assumed the water was saturated to

start with.

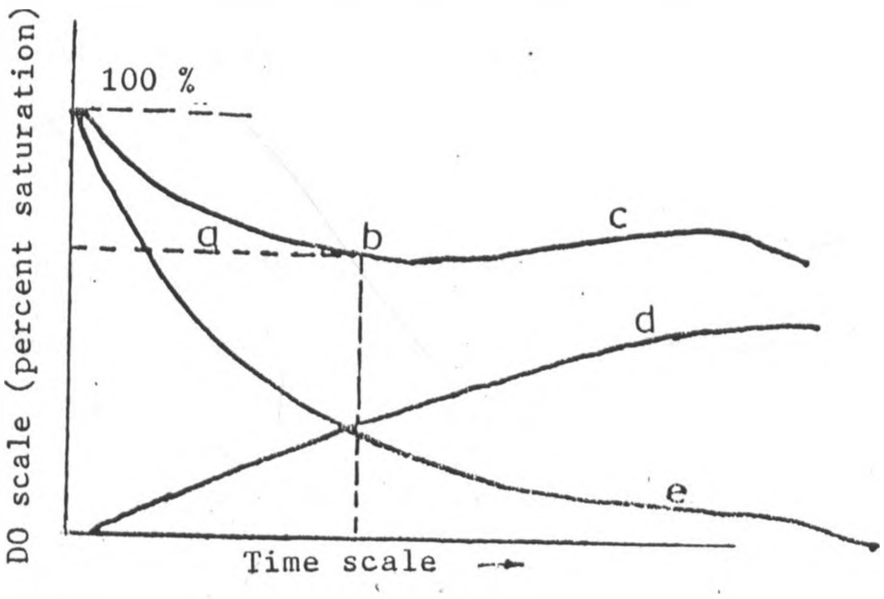

Fig 2.1 Deoxygenation, rearation and oxygen sag curve.

Source Nemerow (1974)

Where :-

a. maximum deficit

b. critical point

c. sag curve (summation of reaeration and deoxygenation

d. reaeration (cumulative)

e. deoxygenation (cumulative)

As deoxygenation and reaeration proceed a minimum DO point result which is called critical point after which the reaeration becomes dominant and the dissolved oxygen starts to rise. The critical DO and the critical time to reach this point are very important to the stream.

According to Churchill et. al., (1962), higher water temperatures increase the rate of molecular diffusion of gaseous oxygen in the surface film of water and thus the rate of

stream reaeration. However, the rate of oxygen solubility also decreases with an increase in temperature and thus the oxygen deficit the major reaeration driving force also decreases.

2.1.3 Bacterial Growth Phases in Stream

Water pollution control investigators have understood that bacterial growth proceeds in continuous phases. This growth have been described as occurring in seven distinctly separate and significant phases as shown in Figure 2.2. The sigmoid growth is very useful, since by analyzing a stream microbiologically one can obtain a good indication of their location on a relative pollution scale. However this curve is more ideal than real.

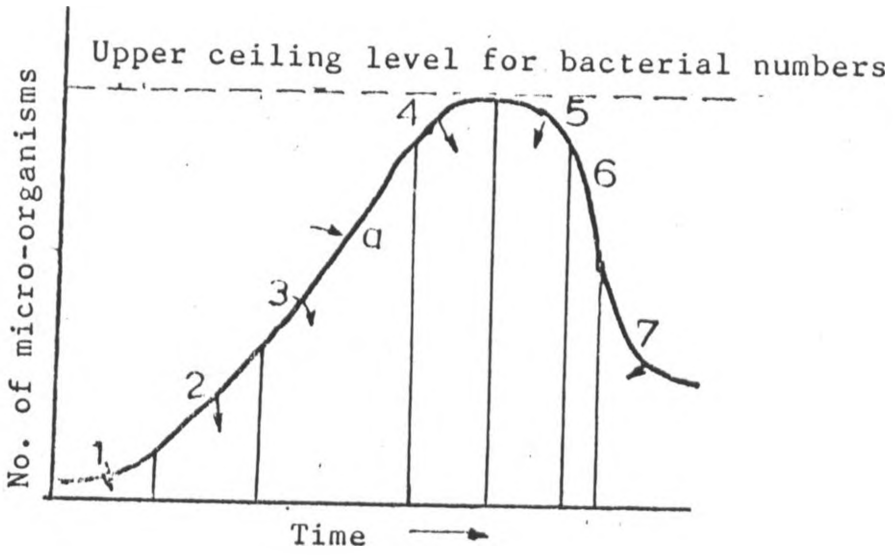

Fig 2.2 Bacterial growth Phases.

Source Nemerow,1974

where :-

a. Maximum rate of increase

1. Stationary phase

2. Accelerated growth phase

3. Logarithmic growth phase

4. Decreasing growth phase

5. Negative growth phase

6. Accelerated death phase

7. Logarithmic death phase

In its early stages, with a constant rate of multiplication per unit of population, the process is autocatalytic in that the rate of addition of new individuals is proportional to the total population which is progressively increasing. This is the well known exponential or geometric rate of increase in population (see Figure 2.1 (point 3)) as shown in equation 2.3.

$$N_t = Ae^{kt} \qquad 2.3$$

where A = a constant

N_t = No of bacterial at time t

k = log a

Ultimately, overcrowding occurs , a situation which can be best described as one exceeding the carrying capacity of the stream due to lack of good supply and accumulation of toxic metabolic products. The population changes from an increasing rate of growth to a decreasing one approaching, finally, an upper ceiling value.

The important factor to remember is that at the midpoint in the growth curve (see Fig. 2-1 point a) there is a maximum rate of increase. The rate of increase, increases for

the duration of exponential growth. When the bacterial population is kept somewhere near this midpoint where mortality equals reproduction, the rate of multiplication remains proportional to the actual food concentration (organic matter).Underlying this relationship is the theory of Biochemical oxygen demand (BOD reaction), in which oxygen is used up by micro- organism in direct proportion to the organic matter remaining.

Predators such as protozoa help to keep bacterial numbers at the logarithmic growth phase. If the food concentration were constantly replenished, an equilibrium would exist between the bacterial numbers and the rate of oxidation. However, in a laboratory BOD bottle and in a stream contaminated with organic matter at one point and undergoing self purification, the food concentration is being continuously reduced downstream from the point of contamination. Thus there is a continual readjustment of the bacterial population to a steadily decreasing food supply in which the rate of bacterial reproduction is automatically maintained at a maximum level and about in proportion to the concentration of available food. This phenomenon is shown in Figure 2.3 .

However, there is one barrier to this oxidation of organic matter which the bacteria carry out the death rate of the bacterial themselves. It is generally accepted that bacteria of all types and especially those of intestinal origin, tend to die out, even under conditions of growth pollution. It is common knowledge that storage, whether it be flowing river or an impounded reservoir, eliminates organisms of sewage origin and other bacteria as well. The death rate appears to be a function of time modified by a marked temperature coefficient.

In the ideal situation when no toxic elements are present, bacteria die in a logarithmic phase. Therefore, they die at a rate according to the numbers of organisms remaining. They do not quite match the logarithmic portion of the death curve, because some of the organisms remaining are more resistant than the ones that die off in earlier stages. The rate of decrease is more rapid at higher temperatures, the initial rate of decrease, is greater since bacterial growth is enhanced to about 40℃. Generally, in higher temperatures, the flow in a stream is low and sedimentation occurs whereas in lower temperatures, sedimentation is lower in the areas of increased velocity of flow.

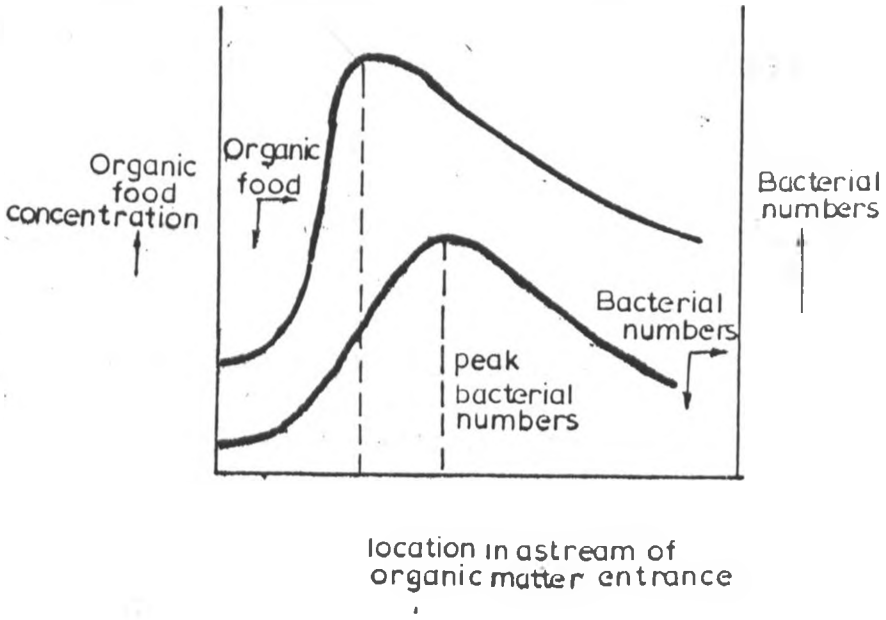

Fig 2.3 Bacterial Self purification as related to watercourses.
Source, Nemerow, 1974

The forces that affect the decrease of bacterial numbers in a stream as reported by Nemerow, (1974) are:

1. Sedimentation: bacteria slowly settle and attach themselves to other aggregates which settle faster. This result in an apparent decrease in bacterial numbers in the flowing water.

2. Protozoa: Ciliated protozoa ingest bacteria.

3. Food supply: Not as abundant as in culture medium. Food is always decreasing due to oxidation.

4. Stream temperature: Below optimum for growth of pollutional bacteria even in dry conditions. Higher temperatures stimulates bacterial in the presence of adequate food and favourable environmental conditions.

5. Sunlight: Sunlight has bactericidal properties but is probably insignificant because of poor penetration of ultraviolet rays, especially in turbid waters.

6. Industrial waste: Seldom contributes many bacteria and mostly results in an immediate and sharp decrease in numbers. Some exceptions exist, such as in potatoes and other food product wastes.

7. Dilution of both food and bacteria by stream water.

2.2 **Industrial discharges and the Kenya legislation.**

As a matter of law, pollution is the addition or doing of something to water which changes the natural qualities of water.To cause pollution the addition should cause deterioration of the purity and quality of the water at that point where the matter enters the water course. In determining whether any matter is causing pollution, polluting substances already in the water should not be taken into consideration. The criterion is whether what is added would considerably pollute the water if it were otherwise pure. (Odero, 1975).

For the purpose of ensuring the proper protection of the environment in Kenya the government has enacted various statutes. These statutes includes the Chiefs Act, the Public Health Act, the Factories Act, the Pest Control Products Act and the Water Act

just to mention a few. The Water Act Cap. 372 is the principal Act in ensuring protection of water resources from pollution.

The powers of Water Act are vested in the Minister of Water Development who delegates the same to the Water Apportionment Board (WAB), who becomes the custodians of the Act. Under section 182 of the Act,the WAB may advice the Minister on the need to make rules for the better protection of water resources from pollution. Rule 72 (i) and (ii) as well as rule 73 and 75 of water subsidiary legislation have been enacted and they empower the WAB to scrutinize and approve any plans and works meant for waste water treatment and to issue effluent discharge standards which an industrial establishment must comply with.

The other statutes which have a bearing towards water resources protection in Kenya include the Public Health Act And the Chiefs Authority Act. Section 10 of the Chief's Authority Act Cap. 128 and Section 12a of the Public Health Act Cap. 242 address themselves to prevention of pollution in those water bodies which are used as sources of drinking water.

As indicated earlier, there is no single unified legislation which deals with environmental protection in Kenya currently. There are various statutes which address themselves to similar ares of environmental protection. While the Acts have not been seen to contradict each other, the same have at times been seen to overlap.The separate Acts have also been found to be lacking in addressing to certain environmental protection aspects. This is very true of the Water Act Cap. 372. While the Water Act is a sound and comprehensive statute and would go a long way in the protection of water

resources, it is deficient in certain areas and some proposals have been advanced for the purpose of strengthening the Act. These proposals are necessitated by the changing situations which require that various institutions charged with the responsibility of management and protection of water resources be given wide powers. In the light of the above it has been established that the Water Act does not provide for the WAB to, among others:-

(a) stop any industrial operations or processes for the purpose of abating pollution.

(b) direct change in industrial processes if they are deemed to be sources of pollution.

(c) order for separation of effluent streams, stoppage of use of toxic substances in industrial processes, reuse of water and effluent equalization and treatment if found necessary.

(d) give consent before the establishment of any industry or during the expansion of any industry.

(e) order and direct the cleaning and restoration of the original state of the environment and recover costs if any incurred.

(f) issue guidelines for industrial processing and inspect industries whenever deemed necessary.

(g) be consulted in all matters touching on the establishment of industries in all sewered urban areas.

(h) demand for environment impact assessment reports on new projects and industries.

Some of the above deficiencies in the Water Act have already been addressed and there is an amended draft where the same have been incorporated.An extract from the

Table 2.1. Industrial effluent discharge standards (proposed)

	Parameter	Into inland Surface water	Into public Sewers	On land for Irrigation	Into Marine C o a s t a l areas
i	Colour	Not objectionable to the eyes			
ii	Suspended solids mg/l max	30	400	200	a, for process waste water 100% b, for cooling water effluent 100% above TSS of influent cooling water
iii	Particle size of SS	Shall pass 850 micron in IS sieve			a, Floatable solid max 3mm b, Settleable solid max 85micron
iv	Dissolved Solids (inorganic) mg/l (max)	2100	2100	2100	

v	Temperature	Shall not exceed 30℃ in any section of the stream within D/S from effluent outlet	40℃ at the point of discharge		40℃ at the point of discharge
vi	pH	6.0 - 9.0	6.0 - 9.0	6.0 - 9.0	6.0 - 9.0
vii	Oil and grease mg/l max	10	20	10	20
viii	Total Residual Chlorine mg/l max	1	-	-	1
ix	Ammoniacal nitrogen as (N) mg/l max	50	50	-	50
x	Total Kieldahl nitrogen (as N) mg/l max	100	-	-	100
xi	Free Ammonia as NH_3 mg/l max	3	-	-	5
xii	BOD, 5 day at 20℃ mg/l max	30	350	100	100
xiii	COD mg/l max	50	100	-	250

xiv	Arsenic as As mg/l max	0.2	0.2	0.2	0.2
xv	Mercury as Hg mg/l max	0.01	0.01	-	0.01
xvi	Lead as Pb mg/l max	0.1	1.0	-	1.0
xvii	Cadmium as (Cd mg/l max)	2	1	-	2
xviii	Hexavalent Chromium as Cr^{+6} mg/l max	0.1	2.0	-	1.0

Source: Water Act Review Draft 1990.

draft showing the proposed industrial effluent discharge standards is presented in Table 2.1. The final draft is at an advanced stage and will soon be enacted into law.

Other Acts which touch in the protection of the water resources have also been revised or are in the process of being revised in order to make in line with the current requirements in environmental protection. It should also be mentioned that the various Acts mentioned here are being reviewed with a view of integrating them into one statute which will address itself to environmental protection through a single agency or authority.

2.3 Brewery effluent and treatment

A review on the nature of brewery effluent requires an insight into the various unit operations and the refractory involved. However, the type and quantity of the product and the wastes produced from a given amount of raw material are a function of the efficiency attained in the supporting operations as well as the yeast and other biological systems. (Briggs, 1981).

In brewing, a malt extract is made from the malt, adjunct materials and hops. This wort is filtered and inoculated with yeast. After fermenting and blending over a period of time, the product is clarified, the carbonation is adjusted and the beer is bottled. The various unit operations in the brewing process are shown in Table 2.2. Major waste discharge routes from a brewery plant are illustrated in Figure 2.4. The brewery waste has a high potential BOD per unit of product caused by residual oxidizable organic material normally remaining in the spent fermentation medium and in unwanted material screened or filtered out when preparing the medium. Also both the prepared medium and the product have high BOD values and if small amounts are wasted through accidents or inefficient processing a heavy load is added to the effluent.

In brewing, a great deal of water is present in spent grains but it is usually too expensive to dry them. Several breweries resort to pressing the spent grains as dry as possible and returning the press liquor to the mashing process. Spent hops and trub, surplus yeast and beer tank bottoms can be pumped to the lauter tun or mash tun before the spent grains are finally discharged. Final wort from mashing can be used in the next brew. Depending on the waste prevention measure adopted by a particular industry, the resulting effluent are of various polluting strengths. Automated cleaning of vessels in which minimum amount of water is used and the cleaning fluids

Table 2.2. Sequence of operations encountered in the brewing process.

	Operation	Input	Product
1.	Milling	Malted barley (+unmalted cereal in some instances	Grist
2.	Mashing in	Hot water	Mash
3.	Mash ingestion	Enzyme and substrate from Grist	Digested mash (wort)
4.	Wort separation (sieving)	Hot water (in a lauter tun)	Sweet wort + spent grains
5.	Wort boiling	Hops, steam in some instances	Hopped +spent grains + hot trub.
6.	Wort clarification	Sieve or settling tank	Hopped wort + hot trub.
7.	Wort cooling + aeration	Refrigeration air or oxygen	Cold aerated wort + cold trub.
8.	Fermentation	Yeast	Green beer yeast + cold trub
9.	Conditioning secondary ferment.	Refrigeration	Carbonated beer ready for filtration
10.	Filtration	Filter sheets	Bright beer
11	Packaging	Packages such as bottles and cars.	

Source: Briggs, 1981

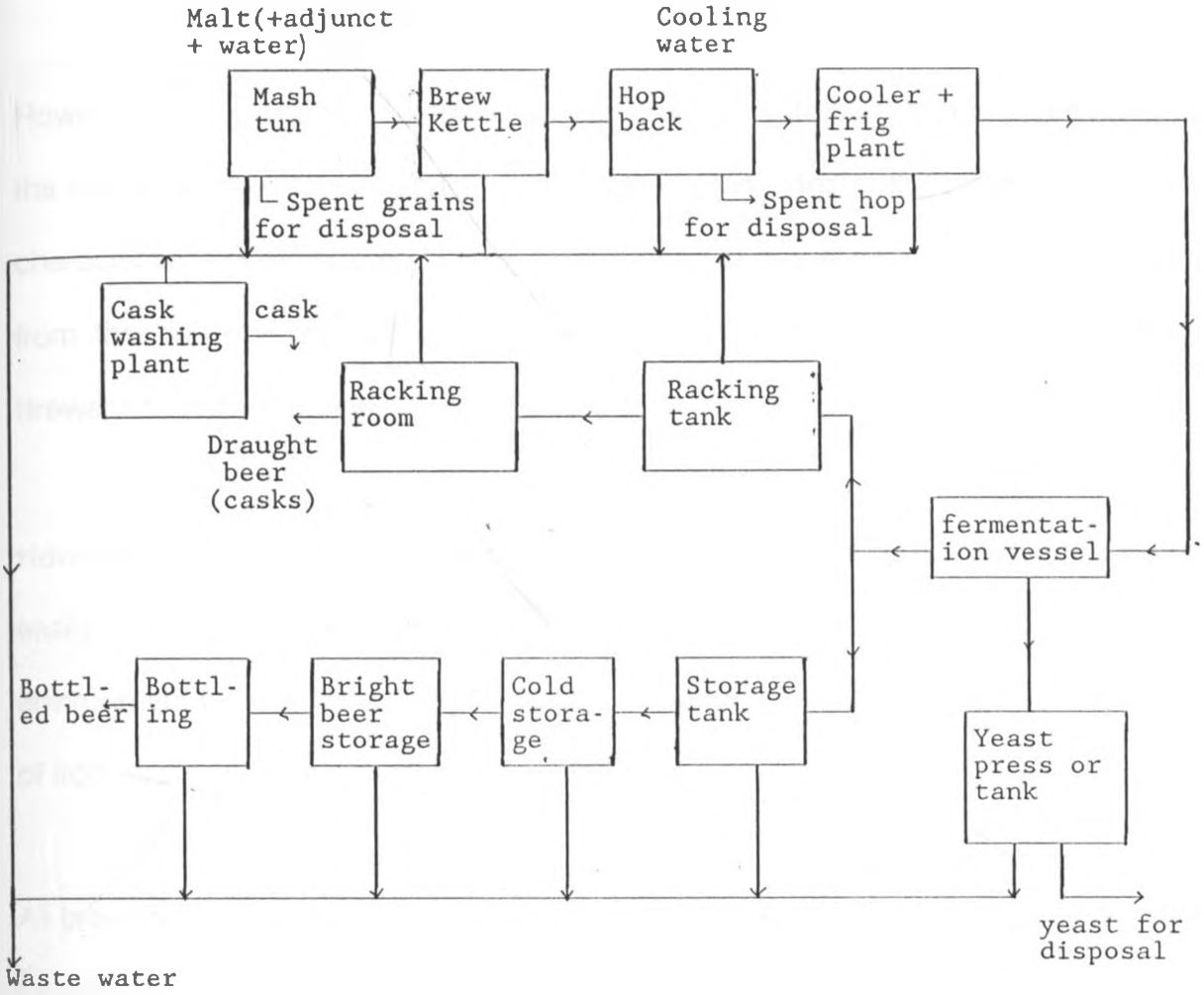

Fig 2.4 Process flow diagram of brewing operation showing major waste discharges.

Source: Briggs, 1981

recirculated and reused, reduction of boiler liquids to a minimum and recirculation of the water in pasteurizers wherever possible will all yield varying effluent depending on the efficiency.

However, as for most organic wastes, the major characteristics of brewery effluent of importance in river pollution considerations are organic strength in terms of BOD, COD

and DO, solids concentration, pH, temperature and volume of waste.

However, it is clear that depending on the in plant waste control measures adopted, the resulting effluent give varying polluting strengths. Rather than look at the overall characteristics of the brewery waste, there is need to look at the various polluting loads from the brewery operations (Table 2.2) to compare with the same from Kenya Breweries Limited, Ruaraka Plant (Table 2.3)

However, because of their relatively high albumen content, brewery wastes putrefy easily and give off gases such as H_2S, NH_4, CH_4 and H_2. The reducing action of the environment causes the putrefying wastes to darken in colour owing to the formation of iron sulphide (Koziorowski et. al., 1972).

All brewery wastes have a very strong influence on receiving waters, particularly small rivers and streams. Their two characteristic features, a high turbidity and deep colour give the receiving water an unpleasant appearance. The high oxygen consumption involved in biochemical decomposition of organic compounds in the wastes causes putrefaction of the river in many cases. This sometimes occurs over fairly long stretches and is accompanied by intense evolution of malodorous gases. The phenomenon is magnified by the formation of putrefying deposits on the bottom and the strong growth of sewage fungi.

In view of the nature of the brewery waste water, it can be readily treated by most of the conventional biological treatment processes. However, it should not be discharged into the sewers until large particles of suspended solids have been removed by

screening. The discharged effluent should be fresh, since putrefying wastes destroy the concrete and lime mortar both in the sewers themselves and in the sewage treatment plant. If this condition is observed, brewery wastes to the extent of 3-5% of

Table 2.3. BOD_5 and SS loads from brewery processes.

Process	BOD_5	SS
	mg/l	mg/l
Mash mixer	519	1052
Lauter tun	27882	18015
Brewkettle (copper)	2850	370
Hot wort tank (sedimentation)	106767	36842
Wort Cooler	207	-
Fermenter	8290	5348
Aging tank	2281	3382
Primary filter	5654	28242
Secondary storage	1049	1532
Secondary filter	885	4557
Bottling tank	125	-
Filter	250	103
Pasteurizer	96	9
Bottler washer	242	99
Cooling water	-	-
Miscellaneous flows	54	54

Source: Briggs, 1981

Table 2.4. Volumes and characteristics of waste water generated from various processes in the Tusker brewery plant, Ruaraka, Nairobi.

Process	Flow l/d	Temp Deg.C	pH	BOD mg/l	COD mg/l	TSS mg/l	TDS mg/l
BREWHOUSE							
Lauter Tun	7415	48.5	4.8	26200	107200	48280	890
Strainmaster	124550	54.0	5.3	19067	35914	25620	480
Decotion vessel	11200			41450	91980	74120	780
COLLECTION VESSELS							
Small (CV)	9797	15.3	4.5	21250	43500	22590	310
Big (CV)	10328	15.0	4.6	23000	48530	30330	435
FERMENTATION & COLD STORARE							
Fermentation Conical Tanks							
1st Prerinse	6540	14.8	6.4	1593	3845	1245	505
2nd Prerinse	6336	13.3	11.8	1890	3850	6900	580
Storage Conical Tanks							
1st Prerinse	2180	14.5	6.5	3490	6500	3950	505
2nd Prerinse	2112	15.3	13.0	3975	8000	2130	500
AUTOLYSED YEAST	21900			68281	190000		
SQUARE FERMENTERS	1504			68278	190000		
SRORAGE VESSELS							
Small (SV)	3445	15.3	4.7	44400	95000	59520	505
600 HL (SV)	1392	14.8	4.2	37700	55000	25925	500
FILTERROOM AND BOTTLING							
Filter aid						1043	
Beer loss	19691		3.7	56000	106250	28300	1000
Bottle washers 1	2880	41.8	10.7	150	1800	350	350
2	3840	46.5	8.7	2652	5455	80	220
3	8400	45.5	12.0	630	1800	100	1300
4	3600	38.0	11.0	900	1800	80	320

Source: Mworia,1986.

the domestic sewage do not disrupt the biochemical processes in the treatment plant, (Briggs, 1981). On the other hand, if acid digestion is too far advanced, the biological treatment processes may be disturbed by a sharp decrease in the pH of the mixed

wastes. To be on the safe side, the naturally slightly acidic brewery wastes are passed through screens and dosed with small quantities of lime.

If the brewery is situated in a small town and there is suitable land nearby, the waste can be treated by broad irrigation thus utilizing the fertilizing compounds in them but have first to be neutralized with lime in order to inhibit acid digestion. Brewery waste neutralize with lime may also be treated successfully by activated sludge if mixed with domestic sewage in the 3 - 5% proportions already outlined. The wastes can also be treated in two stages on high rate filters. Reduction in BOD here is about 90%. (Koziorowski et.al., 1972)

2.4 Models of Water Quality in rivers

Rivers have traditionally been used for the disposal of domestic and industrial wastewaters. In many cases, this has caused undesirable changes to the aquatic flora and fauna. The majority of these changes have been brought about by the discharge of organic matter (BOD) resulting in the lowering in the concentration of the dissolved oxygen (DO) in the receiving water. Pollution of rivers and estuaries is also frequently caused by the discharge of toxic substances, which may break down due to chemical or bacterial action (non-conservative) or which may be resistant to breakdown (conservative) and other problems may arise due to the discharge of inorganic nutrients causing excessive algal growth.

In all of these situations, it is important to be able to relate the rate of discharge of the pollutant to resulting concentration pattern in the receiving water various methods have

been devised for calculating the pattern beginning with the classic work on BOD/DO models by Streeter and Phelps in the 1920. This laid the basis for modelling the chemical kinetics of breakdown subsequent work has concentrated on the hydrodynamic aspects advection and diffusion along with work on stochastic and statistical models and refinement of the kinetic models.

2.4.1 Streeter - Phelps' BOD/DO models

Numerous kinetic models of water quality have been proposed to describe DO and BOD variations along a stream in lakes and reservoirs and in wastewater treatment processes. As earlier mentioned, the first and most widely used model, was proposed by Streeter and Phelps in 1925 for the Ohio river. It states that oxygen uptake is equal to BOD uptake and that both kinetics are first order. Nevertheless, it has been frequently observed that first order curves do not fit well the experimental variations of BOD, so that second-order kinetics were proposed for DO and BOD uptakes. However, their success in describing actual river evolution was not generally accepted. Going by Streeter-Phelps assumptions, two kinetic equations may be written

$$\frac{dl}{dt} = -k_1 L \qquad 2.4$$

$$\frac{dD}{dt} = -k_1 L + k_2 D \qquad 2.5$$

the solutions to which are

$$L = L_o\, 10^{-k_1 t} \qquad 2.6$$

$$D = \frac{k_1 L_o}{k_2 - k_1} (10^{-k_1 t} - 10^{-k_2 t}) + Do(10^{-k_2 t}) \qquad 2.7$$

where

L is the organic matter usually estimated at ultimate BOD.

k_1 is the first order biodegradation kinetic constant

k_2 is the first order oxygen transfer of reaeration kinetic constant

D_t is the dissolved oxygen saturation deficit after time t

L_o is the BOD at an initial reference time, t = O

D_o is the dissolved oxygen deficit at t = 0

However, whatever the improvement brought to the above equations, they will always suffer from the original assumptions.Nevertheless, since different approaches have been taken to the problem, the different approaches differ significantly. In addition the arbitrary selection of a model can bias the results of an analysis. Therefore, the predictive models should be applied only when the conditions are the same as those for which the models were derived (Jorgensen et. al., 1989). The application of a given model outside the range of values of physical variables for which it has been developed can provide significant error.

CHAPTER THREE.

OBJECTIVES, SCOPE AND ENGINEERING RELEVANCE OF RESEARCH.

3.0 Introduction.

The topical and timely subject of water pollution is pertinent to industrialists, environmentalists, ecologists, politicians, policy makers and the general public, all with slightly differing frames of reference.

Concern about water quality is real. The anxiety to characterize water quality ranges from general public concern with the sanitary recreational and aesthetic values of our waterways, through the industrial user of process water and on to legislators accumulating a data base for establishing a meaningful set of quality standards. This research is a necessary element of water quality considerations providing quantitative and qualitative data on existing circumstances and trends of a selected reach of the Ruiruaka river.

3.1 Objectives of the study.

The objectives of the present study were to:

1. determine the physical and chemical status of a selected reach of the Ruiruaka river.
2. attempt to establish the level and extent of pollution cause by brewery effluent in the selected reach.
3. apply a mathematical model in an attempt to simulate the impact of the waste on the river.
4. apply the mathematical model to simulate the impacts on the waste on the river if the waste was discharge untreated in a combined form

through one outlet and also if some form of the pre-treatment of the combined waste before discharge.

3.2 Engineering relevance and scope.

Tusker brewery plant at Ruaraka has been discharging its untreated waste water into the Ruaraka river for along time now. Though not the only industry discharging water into a watercourse, it was felt that since the major product of the brewery plant is beer, a liquid, the ratio of the volume of waste water generated may be a matter of concern. Koziorowski et.al.,(1972) reported the volume of waste produced to be 20-30 times greater than the volume of beer produced. Again going by the raw materials used and the unit operations in the beer production, brewery waste is seen to be a highly polluting organic waste through equally highly biodegradable. It is on that note that need was felt to investigate the effect of the waste on the river the results of which will provide baseline data to reinforce the need for industries to pretreat their effluent before discharge into natural water courses. The results will also be helpful in furnishing data on a typical river system and also serve as an example of the effects of industrialization on tropical water courses.

There is also need to check whether the warm and alkaline bottling hall effluent are neutralised by the cold and acidic brew house effluent. The neutralization, if effective would be a step forward. Model application is done with a view of making recommendation for effluent treatment that will enhance the presentation of Ruaraka as a good source of water supply.

This is river conservation at the grassroots level in the sense that the pollution, if

detected, and measures taken, will help conserve the Ruaraka river as a good source of water and thus relieving the pollution in Nairobi river. It is worth noting here that Ruaraka river drains into the Nairobi river which then drains into the Athi-Sabaki river, a river that supplies water to some coastal towns and finally drains into the Indian Ocean.

CHAPTER FOUR.

EXPERIMENTAL INVESTIGATIONS

4.0 Introduction.

Pollution and natural purification may be measured physically and biologically. Depending on the nature of the polluting substances and the uses that the receiving body of water (or water taken from it) is to serve, measurements may include determinations such as turbidity, color, odour, nitrogen in the various forms, BOD, DO and other gases, mineral substances of many kinds, bacteria and larger aquatic organisms.

When pollutional nuisance of receiving waters is to be avoided, the DO and BOD taken together are generally relied upon to delineate the profile of pollution and natural purification in which engineering calculations of permissible pollutional loading are based. The BOD records in a comprehensive manner the pollutional load placed on the receiving water or remaining in it at any time while the DO identifies the capacity of the body of the water to assimilate the imposed load with or without the aid of recreation by oxygen absorbed from the atmosphere. However, rivers are dynamic systems and are subjected to much variations. A few locations with sufficient numbers of samples to define the results in terms of statistical significance are much more reliable than many stations with only a few samples at each. Velz, 1950 believes its better to concentrate collections during a relatively short interval with intensive sampling when the river regime is stable i.e during a steady hydrograph, rather than to attempt to sample all conditions here and there, now and then during several stages of river flow which usually defines no conditions, requires a longer study period and may be very misleading.

In establishing the level and extent of pollution a certain industrial discharge has on a water course, the following actions and /or hardware items can be manipulated to accomplish the technical objective.

1. Site logistics - getting or being at the location of concern.
2. Securing a representative sample, sampling is representative at discrete instants of time, at a finite number of locations with a specific complement of parameters and on a finite volume of water. The need of compromise is evident, and locations, parameters, volumes, etc. must be carefully chosen to ensure meaningful results.
3. Sample transport. This relates to the movement of the sample between the source point and the point of analysis. Storage and transport must be carried out under conditions which minimise change in the characteristics of interest.
4. Sample pretreatment and processing if need be.
5. Analysis of sample. The measurement can be physical, chemical or any other variety of approach.
6. Display of results. These can be presented by tabulations, plots or profiles with the measured variables plotted against time, geographical displacement, or other independent variables.
7. Record of data. The data can be composed and formatted into computer-compatible codes to provide efficient entry of data for storage functions.
8. Utilization of data. The data should be of relevant engineering interpretation.

4.1 Study Site.

4.1.1 General description of Ruiruaka river.

The river chosen for the study was the Ruiruaka river system. It is one of the main tributaries of the Nairobi river. Rising about 20 km. west of the city of Nairobi, in the southern extremity of the Aberdare ranges, the Ruiruaka river drains on agriculturally rich Kiambu area, which grows a lot of coffee among other crops, into the Karura forest before entering the city at the northern suburb.

Along its course, the river receives sewage, industrial effluent and storm water runoff among other pollutants, before receiving industrial discharges from Tusker brewery plant, Ruaraka. Broken trunk sewers have had their contents flowing into the same river downstream of the brewery waste. There is cultivation going on in most of places along its course. People have also settled alongside the river with some houses barely 5 meters from its banks. The river join the Nairobi river a few kilometres downstream of the brewery plant (about 4 km) at the Dandora area where the pollution load is already large.

4.1.2. Tusker Brewery Plant.

The brewery plant at Ruaraka is the largest in Kenya. It produces approximately 2.25 million litres of beer per day. The factory is situated at Ruaraka, about 6 km from the city centre off the Nairobi-Thika road. Beer production at the Kenya Breweries Limited, Ruaraka plant started on the 14th Dec., 1922 after the company registered on the 8th Dec., 1922. The Ruaraka site was chosen because of a permanent stream nearby to supply the water, namely Ruiruaka river. The buildings to store the equipment was built of stone and corrugated iron. It was a fairly small plant with no pollutional threats.

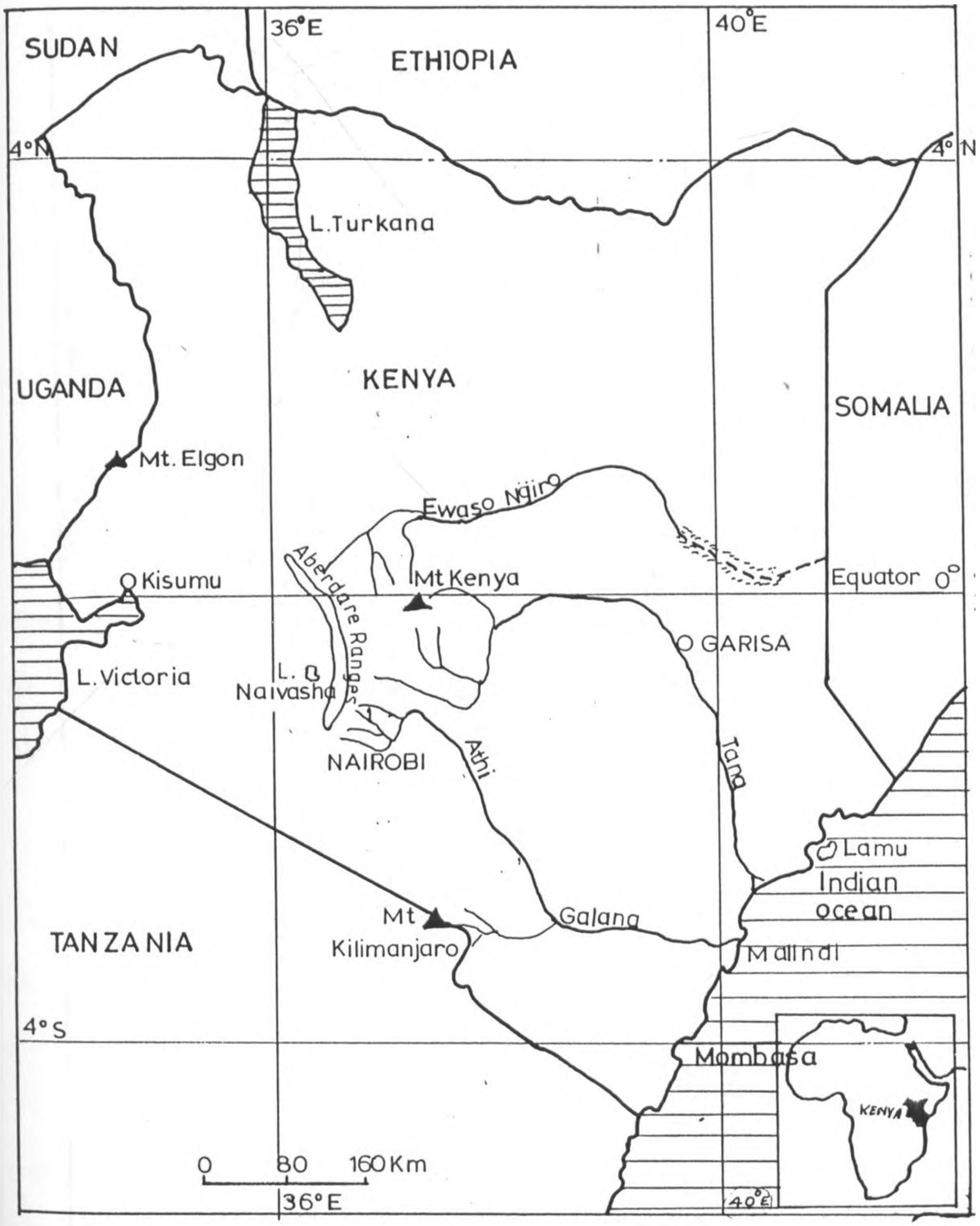

Figure 4.1: Some major rivers of Kenya.

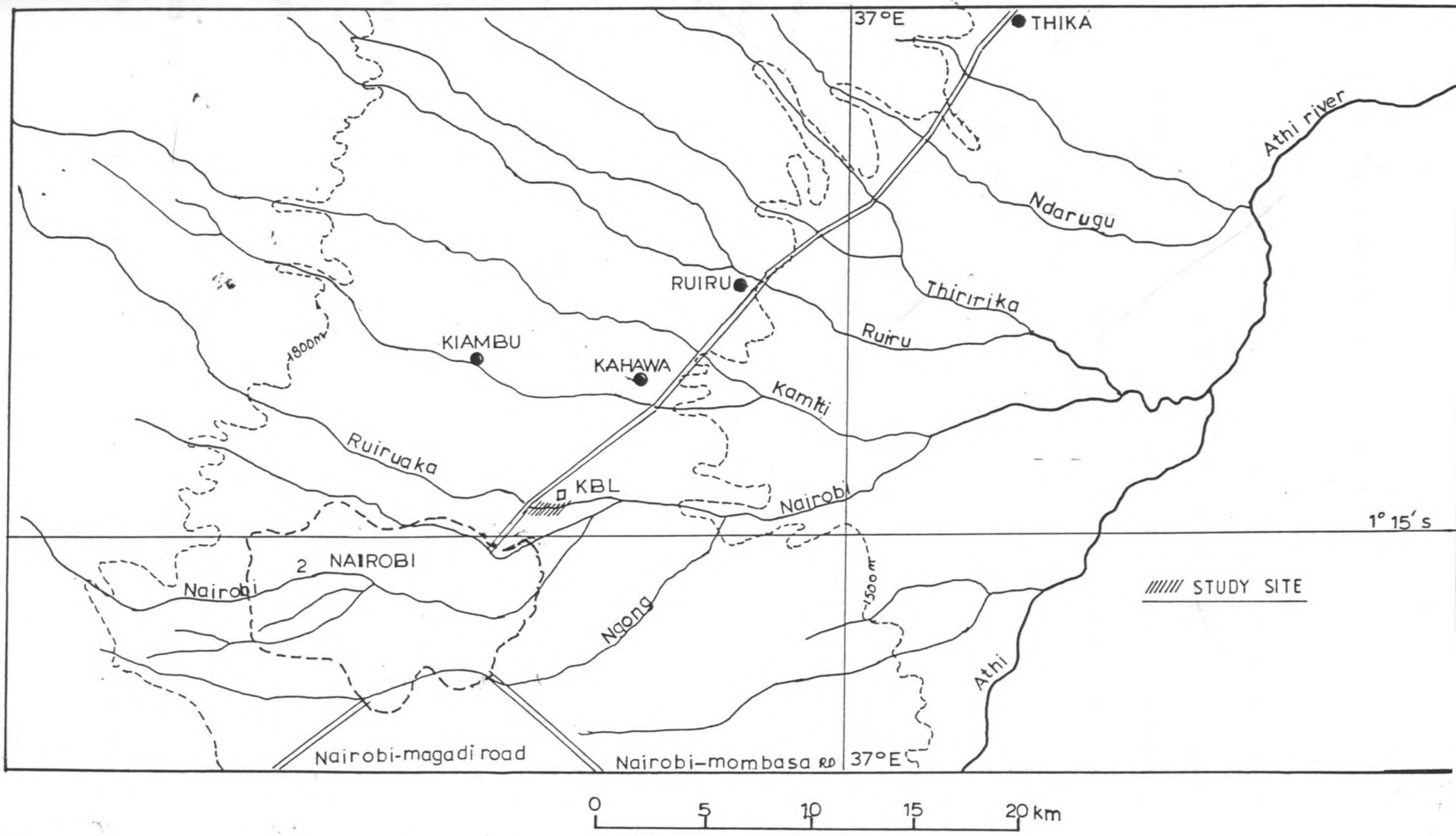

FIG. 4-2: Tributaries of Athi River

The company expanded rapidly in the 50's and the 60's.

Aware of the pollutional reflects that would be caused by the industrial effluent to the Ruaraka river, the effluent were directed to segregated meandering channels dug up in a farm below the plant. The channels were never meant to drain to the river. However, the farm was inhibited by squatters from the neighbouring Kariobangi area and the channels were broken to help irrigate the plots. This messed up the original plan and the effluent started draining into the river.

Though this has been going on for along time now, the brewery management have done nothing about it despite the various researches and proposals to the effect. The brewery produces beer using malt, barley syrup, hops, water and yeast as raw materials. The malting plant is situated in Nairobi's industrial area and so its wastewater does not fall under the study site.

The first stage in the brewery process at Ruaraka is mashing the malt in hot water. The wort produced is passed to the next stage in the process, leaving the spent grains behind. Tusker brewery has a disposal method for the solid bulk of selling the spent grains to the farmers. Hence the spent grains present no pollutional problem as far as the effluent management is concerned. However, the press liquor from the strain-master and the lanter tun which comes from the spent grains contain high BOD load and high amounts of suspended solid.

The next step after mashing and wort separation is boiling at the wort kettles (coppers). At the end of copper boiling, a precipitation of insoluble protein and other

materials occur. The bulk of this hot-break and spent hops have high amounts of suspended insoluble solids and also a proportion of diluted dissolved wort and soluble organic matter. However, the hot-break is usually recycled at Tusker brewery and only when discharged during weekly cleaning does it contribute to a high BOD and suspended solids content.

The hopped wort is then pumped to the whirlpool. Part of the hot-break settles here which again has a high BOD_5 and SS. After the whirlpool, the hopped wort is passed through a heat exchanger to the collection vessels (conical vessels). After pitching, the wort is pumped to the fermentation vessels leaving behind the cold-trub or the cold-break which has a very high BOD and SS.

After fermentation, the problem again is of the high solid content and BOD loads produced in washing down. Yeast particles contribute to a high suspended solid content in the effluent.

This yeast and the dissolved beer gives a high BOD_5 load. The conditioning or the cold storage tanks have some amount of yeast at the end of the day, which have a very high organic load. The effluent from wash downs is equally polluting. However, except for a limited recycling of waste water being practised at the Tusker brewery, most of it is discharged directly into the nearby Ruiruaka river.

Hot liquor from the paraflows is used for mashing. Final rinse water from the bottle washer is recirculated back to the washer. The pasteuriser water is recirculated back to the pasteurisers after treatment. The bottling hall is a major pollution source with

effluent of a very high pH, BOD_5, COD and SS. The volumes are quite high. (see Table 2.1). An adjacent barley syrup plant does not contribute too much pollution. The only effluent would be from waste water of the filter media and floor washing which is quite insignificant compared to the main brewery effluent. Spent grains are sold as cattle feed to farmers. Figure 4.3 illustrate the various Tusker brewery plant, Ruaraka in a flow chart form.

Waste water from the plant is discharged via channel to the Ruiruaka river. At the time of data collection for this study, there were four channels discharging the waste at different points to the river viz, effluent from the bottling hall in two channels, a combined waste from the barley syrup plant (BSP) and the brew house in another channel and the fourth channel conveying waste water from the parking yard where mainly spoilt beers is poured down and forklifts and other vehicles are washed.

4-2 **Sampling Methodology.**

A detailed investigation of the physical and chemical status of the brewery waste water and the Ruiruaka river before and after receiving the brewery effluent was conducted for four months.

During these four months, the wastewater from the brewery plant was leaving the plant through four channels to the Ruiruaka river. Domestic wastewater from offices, toilets in the plant and also waste from the adjacent Tusker village was being discharged to the Nairobi City Commission sewer line which were in turn draining to the Ruiruaka river from a broken manhole along the sewer line. A sixth canal conveying sewage from Ngumba estate and Safari park areas was also draining into the river. It was from

a faulty manhole.

The choice of the sampling station was determined by the desirability of sampling - well protected sites representatives of the various stage of the river pollution. Sampling commenced on 30th October, 1990 and continued twice a week up to 20th February, 1991. Surface sampling was employed throughout the study period. For each point, samples were collected, with a plastic container. Water temperature, dissolved oxygen and pH were determined on site. Colour of the river water was noted and the presence of odour recorded. Land use practice were also noted.

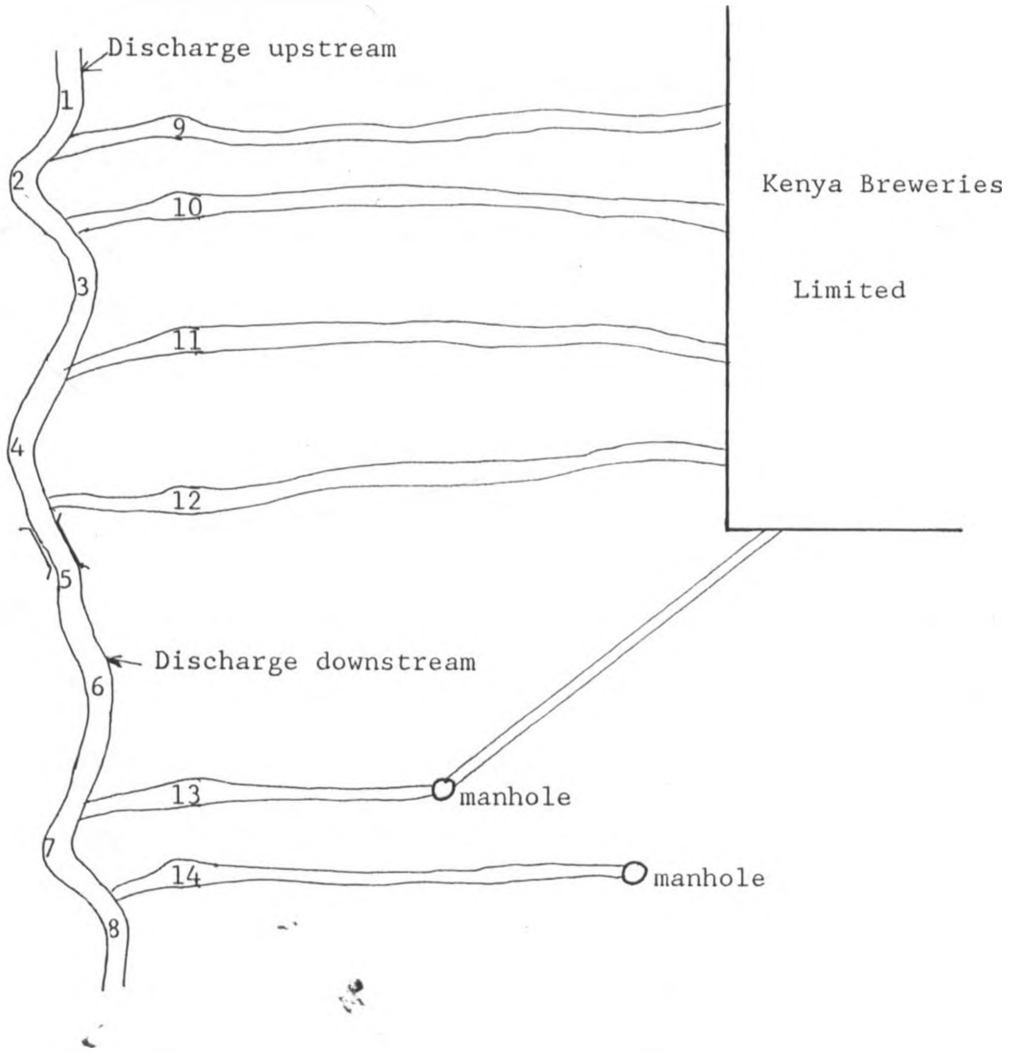

Fig. 4.3 Sampling points on Ruiruaka river and wastewater channels

Station 1. Represent the water quality of the river before the brewery effluent.

2. River after receiving waste water from parking yard and spoilt beer channel.
3. River after receiving bottling and washing waste channel 1 (lines 1 & 2)
4. River after receiving bottling and washing waste channel 2 (lines 3 & 4)
5. River after receiving waste from BSP and brew house.
6. River 155 metres from station 5.
7. River after receiving domestic sewage from offices and Tusker village.
8. River after receiving sewage from Ngumba estate and Safari Park area.
9. Brewery waste from parking yard.
10. Brewery waste from bottling and washing channel 1.
11. Brewery waste from bottling and washing channel 2
12. Effluent from Barley Syrup plant, brewhouse fermenters and storage.
13. Sewage from Tusker village and offices.
14. Sewage from Ngumba estate and Safari Park areas.

The samples were then transported by road to the Ministry of Water Development laboratories in Nairobi's industrial area about 7 km away for analysis of BOD_5, COD, suspended and dissolved solids. The tests and analysis were performed according to Standard Methods (1985).

River gauging for discharge and velocities of flow both upstream and downstream of the brewery discharge channels was done once a week during the same period.

CHAPTER FIVE.

RESULTS AND DISCUSSIONS.

5.0 Introduction.

The biochemical factors in stream analysis include many organic and inorganic chemical constituents other than BOD and dissolved oxygen. However, whatever the parameters used to describe the situation, the word pollution and a polluted water are relative terms and expressions to describe them may be adversely biased.

Moreover, it is often easier to interpret chemical analysis data fairly when they are supplemented by observation on stream flows and rainfall, by data on the volume and frequency of discharges to the stream and by other relevant information on the prevailing conditions and the site. In this study, pH, temperature of the river water, suspended and dissolved solids, BOD_5, COD and dissolved oxygen measurement were carried out to illustrate the pollution under study.

The data collection having been done from November 1990,(a wet spell) through to February 1991 (a dry spell) displayed varying physical characteristics in the river. All this time intensive gardening was being carried out no both sides of the river. Around November and December about which time the river was occasionally muddy brown at times of heavy rains, odorous conditions persisted at times of low flow resulting from low dilutions of the brewery effluent.

Extremity in the physical, chemical flow characteristics of the effluent was evident in a matter of seconds. Despite the above, people from the squatter villages used the river water for domestic, laundry, bathing, and brewing illegal alcoholic drinks. Table 5-2

illustrates the range and average of parameters monitored in the study while the raw data is in Appendix A.

5.2 Results

1. Discharge.

The discharge measured upstream of brewery plant closely followed rainfall seasonal variations. The highest flows with occasional flooding occurred during the short rains in November and December. Dry seasons occurred in January and February and were characteristics by very low flows. During the sampling period, a peak flow of 1.496 m^3/s was recorded on 8th Oct, 1990 and the lowest of 0.627 m^3/s on 12th Feb. 1991.

An average effluent discharge volume of 6.3 million litres per day was recorded over the sampling period. This is about three times the beer produced. The brewery produces about 2.25 million litres of beer daily.

The discharge contributed by the brewery varied considerably depending on the works being done in the industry at the time of sampling. This, coupled with the rainfall seasonal variations gave varying figures for discharge downstream. An average effluent dilution ratio of 1:14 was recorded during the sampling period with the highest ratio of 1:29 recorded on 1/12/90 and the lowest of 1:6 recorded on 28/1/91.
The greatest effluent contributor in terms of flow was the bottling hall. The combined waste from the brewhouse and the barley syrup plant ranked second in terms of flow. A low but significant flow come from the parking yard where spoilt beer, vehicle washing, etc. are drained.

Table 5.1. Location, characteristics and physical status of sampling stations in the selected reach.

Station	Distance below 1st station. (m)	Characteristic of station.	Physical status of and around the station.
1	0	River upstream of brewery.	Fast, turbulent flow.Shallow, clear and cool water.Cultivation on both banks.
2	265	River after receiving effluent from parking yard.	Slow moving water.River very wide and deep.Cultivation along both banks.Slum village hardly 50m away.
3	315	River after receiving effluent from bottling hall channel 1	Fast and turbulent.River is narrow.Nappier grass and bananas along the banks.Smell of NaOH.
4	425	River after receiving effluent from bottling hall channel 2	River fairly fast.Swimming spot for boys.Water collection point.Cultivation on one Low cost houses hardly 50m away.Broken bottles disposal site hardly 30m away.The bottles have been swept by flooded waste channels and can be seen along the banks;a sign of broken bottles in the river.Smell of NaOH.
5	590	River after receiving effluent from BSP and brewhouse	River slow and wide.Spent grains visibly obvious in the river all the but slightly in abundance from time to time.Strong alcoholic odor persistently present.
6	749	River 155m from station 5 No effluent in between.	River wide and faster than station 5.Spent grains and strong alcoholic odors obvious.
7	815	River after receiving sewage from a broken sewer main conveying Tusker village and offices wastes.	River wide and fairly fast. Cultivation on one side and nappier grass on the other. Spent grains obvious.Alcoholic odors persistent.
8	995	River after receiving broken sewer contents from Ngumba estate and Safari Park areas	River narrow and fast.Nappier grass on both banks.Spent grains obvious.Slight alcoholic odors.

2. Temperature.

Temperature is an important controlling factor in the biological processes occurring in the catchment either acting singly or in conjunction with other environmental factors. In fact river water may be said to be the primary environmental factor influencing the distribution of the well being of aquatic communities. During the study a difference of 6^0C in temperature was observed between upstream and downstream of the brewery. The lowest recorded was 23° C while the highest was 29° C..

As expected the river water temperature downstream was largely governed by the temperature of the brewery effluent with the bottling hall discharging hot effluent at times. The highest value recorded for the bottling hall was 37^0 C. However, the effluent from the brewhouse (station 12) was extremely cold at times (lowest 20^0 C) and therefore the effects cancelled out on entering the river thus ruling out thermal pollution.

3. Dissolved oxygen.

The river is fairly aerated before receiving the effluent. However, it kept going down after every effluent discharge entry and always recorded the lowest after receiving the last channel effluent. The lowest recorded during the study was 0.7 mg/l. 155 m from the last channel from the brewery gave a slightly higher DO showing signs of recovery. The highest DO figures recorded upstream of brewery of 7.1 mg/l was in November while the lowest figure of 2.5 mg/l was recorded in February. Generally on the river, there is a direct relationship between discharge and dissolved oxygen concentration with the maximum occurring during high discharge periods and lowest during low discharge periods. A significant sharp decrease in DO was evident after receiving

wastes from brewhouse and BSP which a very high organic load.

With the disappearance of oxygen, the stream becomes septic and oxidation gives way to fermentation. The resultant is a predominance of saprobic black masses in the water (Hartman et. al., 1972). Low oxygen concentration are always correlated with high loads of organic pollution since the beer activity of saprophytes reduces the oxygen concentration considerably.

4. Biochemical Oxygen Demand (BOD_5)

As the river receives the first waste water channel from the brewery plant, the BOD_5 suddenly rises and continues that rise after every additional effluent. The sudden increase is greater after receiving the waste water from brewhouse and BSP with as high a BOD of 450 mg/l but gradually declines downstream though the very low initial concentrations are not regained as the river encounters more waste from broken city commission sewers also draining into the river. All the waste water channels had a very high BOD_5 concentration with the brewhouse and BSP channel producing as high a BOD_5 as 14,000 mg/l.

Seasonal BOD_5 variations is evident from the data collected with low concentration values found during the wet season and the high concentration values found during the dry season. This was seen to go by the diluting capacity of the flow as was explained for dissolved oxygen. However, the exception of the difference in magnitude, the COD data follows the same interpretation as the BOD_5 data.

5. pH.

The river before receiving any effluent had a rather neutral pH of 7.3 average recording 6.6 as lowest and 8.2 as highest values. The first channel of waste conveying spoilt beers and other wastes from the parking yard was of an acidic nature pH 5.5. Brewhouse and BSP wastes in another channel were also acidic (pH 5.40. This neutralises with wastes from the bottling hall which was alkaline in nature (pH 8.7 and 8.1 for 2 different channels). From this it can be analysed that pH is not a problem as far as pollution is concerned as the river records a fairly neutral condition of pH 7.1 after receiving all the brewery wastes. This was unlike the other parameters monitored.

6. Total Dissolved Solids. (TDS)

The total dissolved solids increased slightly from 127 mg/l upstream before effluent entry to 388 mg/l downstream after all the waste had been collected. It was seen to shot up with every effluent entry. A slight decline was observed 155 m from the last sampling point after brewery downstream. The effluent have very high TDS values again the greatest TDS being from brewhouse and BSP of 2195 mg/l mean.

7. Total Suspended Solids (TSS)

The amount of total suspended solids in the Ruiruaka river system upstream of the brewery waste is slightly dependent on the rainfall patterns. Total suspended solids during high discharge were much higher than those levels occurring during the low discharge periods. This is mainly due to influx of eroded material during the heavy rains. Brewery effluent had very high values for suspended solids with the channel from brewhouse and BSP having the highest values of 2508 mg/l on average with

some extraordinary figures of 11465 mg/l recorded. This suspended material from the various brewery effluent channel brought about a gradual increase in the suspended solids concentration in the river for every subsequent station downstream. A spell of run downstream of all brewery effluent gave slightly lower values showing some settlement.

Table 5.2. Range and average values of parameters analysed from the various stations

Stn	BOD mg/l	COD mg/l	DO mg/l	pH	TEMP Deg.C	TDS mg/l	TSS mg/l
1	0.2-41 16	1.2-87 34	2.5-7.1 4.9	6.6-8.2 7.3	23-27 25	101-181 127	4-85 41
2	0.8-56 24	1.8-97 48	2.0-7.0 4.3	6.5-9.0 7.3	23-29 26	90-287 188	30-126 67
3	2.0-72 30	6-124 65	2.0-6.8 4.0	6.2-8.7 7.3	24-30 27	125-562 249	26-149 80
4	6.0-110 47	19-196 94	1.7-6.5 3.5	6.5-7.9 7.2	22-30 27	143-574 302	58-232 130
5	7.0-450 106	23-702 216	0.7-6.3 2.7	6.2-9.1 7.1	23-28 25	202-686 388	47-664 238
6	8.6-390 96	18-619 189	0.8-6.4 2.9	6.5-8.8 7.1	23-27 25	184-566 379	43-576 219
7	14-350 102	38-546 188	1.0-5.2 3.1	6.5-7.5 7.1	23-28 25	195-517 364	92-512 240
8	12-340 101	83-514 197	1.7-5.3 3.2	6.8-7.5 7.1	24-27 25	114-602 333	73-392 175
9	300-6100 2145	1267-9784 4235	0.3-2.8 1.3	3.2-9.4 5.5	20-30 26	531-7597 2058	115-952 483
10	92-1100 440	180-3795 998	0.5-4.5 2.2	5.9-13.0 8.7	25-37 32	148-1210 530	40-130 91
11	71-1160 454	140-3118 982	0.7-4.2 2.0	5.0-12.7 8.1	25-35 30	266-1482 631	49-189 95
12	850-12000 4385	1715-25660 8304	0.0-1.6 0.8	3.0-7.9 5.4	20-30 26	450-6713 2195	322-11465 2506
13	89-470 225	157-834 462	1.3-3.5 2.3	6.5-7.8 7.0	22-30 26	276-1348 581	129-841 442
14	76-240 166	126-505 232	1.8-3.6 2.6	6.5-8.2 7.2	23-29 26	89-891 382	52-652 188
CE	850-4200 2211	1424-7465 3859	0.6-2.0 1.4	5.6-9.9 6.8	-	662-2339 1406	362-2561 676

CE - Combined effluent (stations 9,10,11 and 12)

Table 5.3. Results of Ruiruaka river discharge, velocity, effluent volume and the resulting dilution ratios.

DATE	UPSTREAM		DOWNSTREAM		VOLUME OF EFFLUENT ($x10^6$) L/d	EFFLUENT DILUTION RATIO
	Q M^3/S	V M/S	M^3/S	M/S		
1/11/90	1.428	0.516	1.491	0.428	5.4	23
9/11/90	1.024	0.403	1.099	0.378	6.5	14
23/11/90	1.390	0.454	1.454	0.406	5.5	22
1/12/90	0.826	0.379	0.854	0.335	2.4	29
8/12/90	1.496	0.537	1.611	0.438	9.9	13
13/12/90	1.204	0.426	1.251	0.394	4.1	26
20/12/90	0.924	0.397	1.042	0.360	10.2	8
28/12/90	1.126	0.418	1.191	0.390	5.6	17
4/01/91	1.294	0.437	1.362	0.401	5.9	19
12/01/91	0.728	0.330	0.780	0.315	4.5	14
21/01/91	1.102	0.414	1.144	0.385	3.6	26
28/01/91	0.920	0.388	1.068	0.369	12.8	6
5/02/91	0.827	0.357	0.900	0.340	6.3	11
12/02/91	0.627	0.306	0.712	0.294	7.3	7
20/02/91	0.727	0.322	0.787	0.320	5.2	12
AVERAGE	1.043	0.406	1.116	0.370	6.4	14

D - Discharge V - Velocity

settlement. However, this could not be maintained as there was more suspended solids coming in with additional waste water from broken City Commission sewers.

5.2 Streeter - Phelps Model Application.

The importance of mathematical model as in ecology in general and more specifically in water quality control have been strongly emphasised by James 1973. A simple model is used here to illustrate the effect of pollution on the self decreasing process in the Ruiruaka river.

5.2.1 Application on data collected.

The Streeter-Phelps analysis was performed on the raw data which was obtained from the survey. The following are the equations used in determining the rates of deoxygenation and reaeration and the Streeter-Phelps equation.

k1, deoxygenation rate for the river conditions

$$k_1 = \frac{1}{t_{5,6}} \log_e \frac{l_5}{l_6} \qquad 5.1$$

where the river flows from station 5 to 6

$t_{5,6}$ is the time of flow between stations 5 and 6

l is the ultimate first stage BOD_5 at each station.

correcting for temperature,

$$k_{1(T\,C)} = k_{1(20^{\circ}C)} \times 1.047^{(T-20)} \qquad 5.2$$

where, T is the water temperature at station 6

k_2, reaeration rate for the river condition

$$k_2 = \frac{(k_1)(l)}{D} - \frac{D_6 - D_5}{2.3D(t_{5,6})} \qquad 5.3$$

where the river flows from station 5 to 6

l is the average value of BOD_5 from station 5 to 6

D is the average value of DO deficit

D_5, D_6 is DO deficit at point on the river

$t_{5,6}$ is time of flow from 5 to 6

correcting for temperature

$$k_{2(T\,C)} = k_{2(20^{o}C)} \times 1.0241^{(T-20)} \qquad 5.4$$

where, T is the water temperature at station 6

The Streeter-Phelps equation used is:

$$D = \frac{k_1 Lo}{k_2 - k_1}\left(10^{-k_1 t} - 10^{-k_2 t}\right) + Do\left(10^{-k_2 t}\right) \qquad 5.5$$

D is DO deficit at any time of flow t

Lo is initial BOD_5 load in the river

Do is initial DO deficit in the river

t is the time of flow

The Streeter-Phelps analysis described the affect of an organic load on a river's dissolved oxygen content. The assumptions made to apply this analysis are that the river's reaeation rate is constant, the rates of reaeation and deoxygenation follow logarithmic paths, and the flow and flow time are constant across the reach of the river.

5.2.2 Application on combined effluents

Alongside the brewery effluent evaluation, the effluent from parking yard and spoilt beers, bottling hall channels 1 and 2 and waste from brewhouse and BSP were mixed in the ratio 1:1:1:1 respectively and analysed for pollutional strength. This was done

on the understanding that if the brewery management decided to discharge their waste via one channel, it would be of the characteristics achieved. The condition of the river was then determined using the equations:-

$$BOD(d/s) = \frac{Q(u/s)xBOD(u/s) + Q(waste)xBOD(waste)}{Q(d/s)} \quad 5.6$$

$$DO(d/s) = \frac{Q(u/s)xDO(u/s) + Q(waste)xDO(waste)}{Q(d/s)} \quad 5.7$$

where

BOD(d/s),DO(d/s) are the BOD_5 and DO of the river after mixing with the waste

BOD(u/s),DO(u/s) are the BOD_5 and DO of the river before receiving any waste

BOD(waste), DO(waste)BOD_5 and DO of combined effluents respectively,

Q(u/s) river discharge upstream,

Q(d/s) river discharge downstream,

Q(waste) effluent discharge

Assuming the same values of k_1 and k_2 in the river, the Streeter- Phelps analysis was performed on the data. The flow time and the temperature of the river downstream were assumed not to change.This gave a calculated DO value at station 6 to compare with the observed values.

5.2.3 Application on an assumed pollutional load reduction

The brewery management are aware of their effluents' high polluting load and have recommended for effluent pretreatment before discharge into the Ruiruaka river. An

activated sludge system have thereby been suggested as a possible option, (Mworia, 1986). Assuming they researched further and put up a system capable of reducing the polluting load to the proposed standards on industrial effluent discharge, (Water Act review draft, 1990) the Ruiruaka river will accordingly be relieved of the pollution. Using an effluent BOD_5 discharge of 30 mg/l and DO of 2.5 mg/l, the BOD_5 and DO concentration of the river after mixing with the waste was determined in the same way as in section (ii) above.

Table 5.4. Dissolved oxygen values as observed and after model application.

Date	k_1 $\log_e$	k_2 $\log_e$	Observed DO mg/l	Calculated DO real situation mg/l	Calculated DO combined effluent mg/l	Calculated DO pretreated. effluent mg/l
1/11/90	19.8	142.7	4.5	4.5	0.5	7.8
9/11/90	-15.2	-216.7	2.8	-	-	-
23/11/90	17.6	105.7	6.0	5.8	-0.1	6.8
1/12/90	9.2	93.1	3.8	3.5	4.6	6.3
8/ 2/90	11.6	163.4	2.8	2.4	-6.8	5.9
13/12/90	13.3	125.4	2.5	2.2	2.4	6.2
20/12/90	13.0	193.5	3.5	3.4	-16.5	7.0
28/12/90	-56.3	-192.4	6.4	-	-	-
4/01/91	27.9	395.9	3.8	3.8	2.2	7.9
12/01/91	10.2	134.4	2.3	1.9	0.3	6.2
21/01/91	15.6	233.5	3.3	3.1	4.0	6.5
28/01/91	17.9	728.9	1.9	2.0	-3.8	8.1
5/02/91	19.5	583.7	2.5	2.6	2.8	7.6
12/01/91	15.1	201.7	2.7	2.5	-11.8	6.8
20/02/91	20.5	343.4	1.8	1.8	-0.2	6.9

5.3 Discussion.

Widespread effects of river pollution are best shown in terms of reduced dissolved oxygen (DO) levels and increased biochemical oxygen demand (BOD). Hynes (1960) has emphasized the value of the BOD test as the most important measure of the polluting power of organic effluent. BOD_5 data gathered for the Ruiruaka river during the present study indicate low levels of organic pollution in the river before the brewery

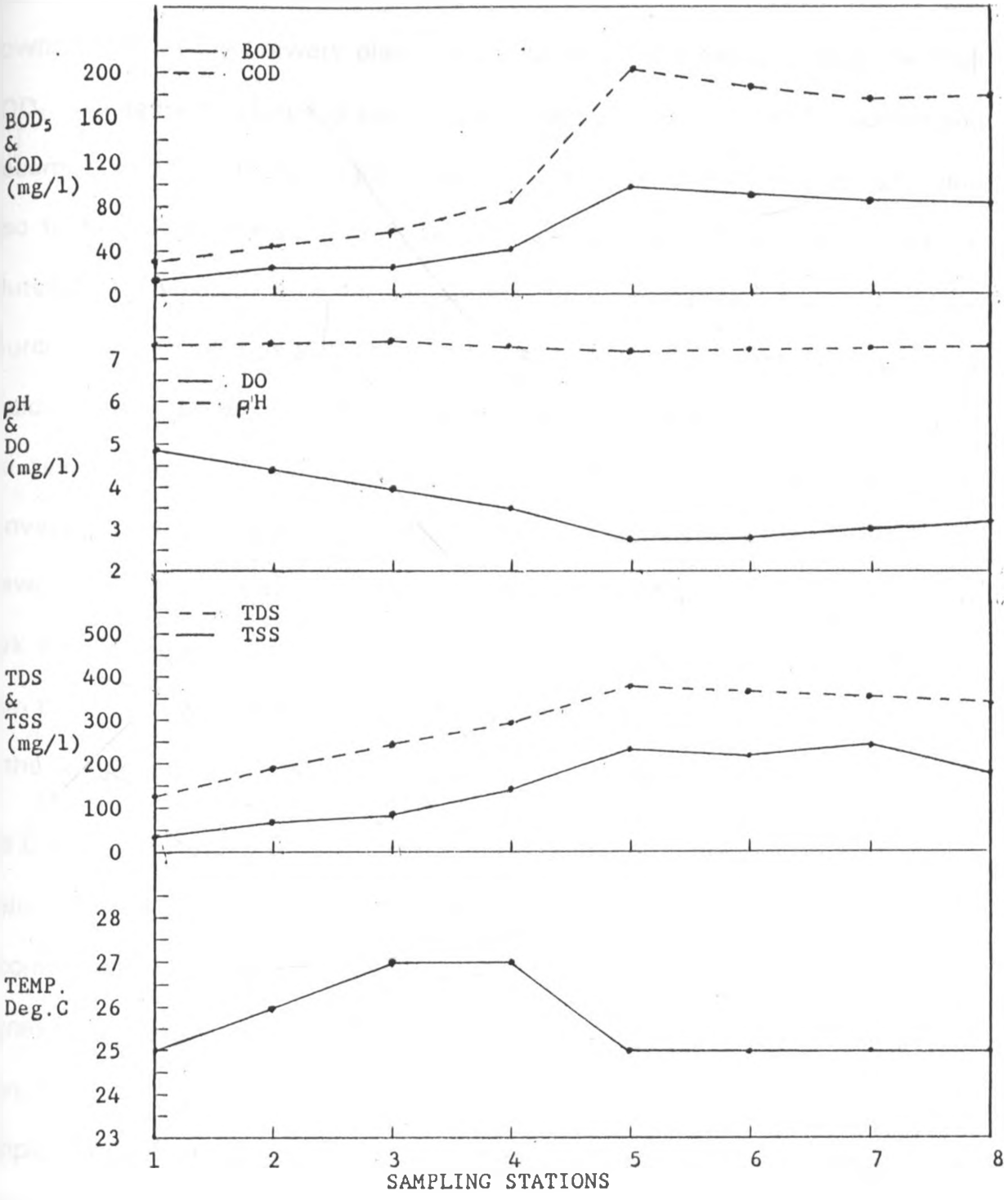

Fig. 5.1. Variations in the various parameters analysed.

plant. As expected, maximum BOD_5 was found in the section within and downstream of the brewery plant. It would have been expected that the high BOD_5, values be measured in the river upstream of brewery over November and December which is the coffee pulping season. However, the same months happen also to fall within the short rains seasons and so the high polluting loads are diluted.The development of an oxygen sag curve downstream from a polluting source has been used as one of the better indications of pollution. However, this could not easily be done for the brewery waste as it was not the only pollutant in the selected reach. Two broken Nairobi City Commission sewer mains, one conveying sewage from Tusker village and other domestic sources within the brewery plant and the other conveying the same from Ngumba estate and Safari Park areas drained into the Ruiruaka river hardly 200m and 300m downstream from the last brewery effluent channel respectively thus making the development of the oxygen sag in terms of brewery effluent only unrealistic.

The BOD profile is more or less a mirror image of the DO profile. Such profiles are useful in defining the different zones that are in turn dependent on the stage of decomposition / self purification reached by the time the water passes a given point (Hynes, 1969). As in most biological phenomena, these zones are not clear cut with sharp boundaries but are transitional. However, the process of the self purification is complex and each stream is a unique ecosystem with its own capacity, purification and recovery (Bernade, 1970). A longer time of flow and a longer distance downstream of the brewery effluent discharge points were required while sampling the river for determination of the deoxygenation and reaeration rates k_1 and k_2 respectively in terms of the pollution caused by the brewery effluent exclusively as the author may have wished. However, such along distance could not be achieved as more waste water

entered the river in less than 200m downstream of the last brewery effluent channel. This might explain the abnormally high k_1 and k_2 values. Rich (1973) has recommended a k_2 value of 0.2 - 10 d^{-1} as the normal range for non-tidal rivers.

The BOD_5 value of 450 mg/l recorded after the last brewery effluent channel and an equally high COD value of 702 mg/l are a clear indication of a polluted river. This, in fact falls in the range of middle strength of sewage as classified by Mara, 1978.

The dissolved solids were found to be in most cases higher than the total suspended solids in the various stations sampled along the river. Before the brewery effluent, lower total dissolved solids were associated with higher water levels, a manifestation of the dilution effect. This pattern is however distorted with the entry of the brewery effluent. Bodies of water containing a total dissolved solids concentration value of 100 mg/l are considered oligotrophic while values above this are generally considered to represent eutrophic conditions (Andrews, 1972). The total dissolved solids concentration in the upstream section immediately before brewery effluent in the Ruiruaka river ranged 101 - 181 mg/l and although the river should be classified as eutrophic according to Andrews (1972) it is not so in a practical sense. After the brewery effluent are discharged the total dissolved solids ranges 202 - 560 mg/l (station 5). These values are comparable to the total dissolved solid concentration of 503 mg/l contained in Nairobi raw sewage (Mara 1978).

Though Ruiruaka river passes through the heavily cultivated Limuru area, it does not appear to have a high concentration of suspended solids before meeting the brewery effluent. This could be attributed to its passing through Karura forest hence not much

disturbances. The effluent from brewery plant contribute much of the silt load carried by the river.

A highly polluting channel conveying wastes from brewhouse and the Barley syrup plant (BSP) is responsible for the increased sediment load in the Ruiruaka river. Arising last among the brewery effluent channels, the brewhouse and BSP channel conveying a high volume of grey/brown waters, smelling strongly alcoholic and the spent grains and filter media used in the factory visibly evident. The total suspended solids ranges 322 - 11465 mg/l. Though diluted after emptying into the river, the color, the smell and the suspended particles strongly persist with the total suspended solids ranging 65 - 664 mg/l. This compares well with the suspended solids concentration of 550 mg/l in Nairobi's raw sewage as reported by Mara (1978). The spent grains can be seen way down the river about 1 km downstream. Cultivation of land immediately near the river bank and lack of soil conservation have also contributed to the increased sediment load. While some fishes can tolerate high turbidities for short periods, total suspended solids of more than 100 - 200 mg/l are usually harmful or even fatal. (Hickling, 1975).

Turbidity resulting from high sediment load makes the river aesthetically objectionable and also increases the cost of treatment for domestic and industrial processes.

The Ruiruaka river shows relatively no change of water temperature after receiving the first brewery effluent channel i.e. from spoilt beers and parking yard, a progressive rise after receiving the waste from bottling hall and a noticeable lowering after receiving waste from brewhouse and BSP.

Waste from the bottling hall is usually warm waste having been used in the pasteurizer while that from brewhouse is usually cold having come from cold rooms. However, an increased temperature should have the effect of speeding up the process of self purification within the river, with a resultant increase in the ability of a river to receive and purify pollution load (Caspers, 1974).

There was a marked rise in the river temperature at all stations over the January and February months. This could be attributed to the low flows in the river and the hot season resulting to low dilutions of the effluent.

The water in the river, constitutes a fairly neutral system with a pH of 6.2 - 8.2 (station 5) after receiving the wastes compared to a similar range of 6.7 - 8.3 before receiving the waste water. The brewery effluent would therefore seem not to affect the pH in the river. This would be explained by the fact that the effects caused by the alkaline waste from bottling hall of pH range 6.9 - 13.0 for the first channel and 0.9 - 12.7 for the second channel are neutralized by the effects caused by the acidic nature of the waste from brewhouse and BSP of pH range 3.0 - 7.7.

Brewery waste may be discharged to the river where the volumes involved are relatively small. Briggs (1981) considers a ratio of 1 volume of brewery effluent to every 500 volumes or more of unpolluted river as satisfactory. However, in this study, an average dilution ratio of 1:14 was recorded. This is by far too small a dilution for effluent discharge into a water course.

Koziorowski et. al., (1972) reported the volume of waste produced to be 20 - 30 times

greater than the volume of beer produced. However, during the study period, a range of 2.4 - 12.8 million litres per day in volume of effluent discharged was recorded. This was about 6.3 million litre per day on average. This, compared to 2.25 million litre of beer production per day at Tusker brewery, is only about 3 times and not the 20 - 30 times in literature. It has been earlier stated that the effluent have at times been diverted into small plots by squatters for irrigation. This coupled with the fact that the volume of effluent discharged will highly depend on the waste water control measures adopted, explains the variation in the ratio of the volume of beer produced to the effluent discharged.

Moreover, it is a fact that depending on the waste prevention measure adopted by a particular industry, the resulting effluent are of various polluting strengths. It is therefore felt that if Tusker brewery proposed the waste water control measures adopted in section 2.3, the pollution on the Ruiruaka river would be highly reduced.

It was wished that the data collected would be used to obtain a profile of the river downstream of the brewery plant illustrating the effects of the brewery effluent on the self purification process in the Ruiruaka river. However, this was not to be because as previously mentioned, there were other sources of pollution barely 200m away from the last brewery effluent channel thus making it difficult to obtain the said profile. Station 6, the furthest point downstream of the brewery's effluent channels before the other additional waste was therefore used in determining the deoxygenation and reaeration constants, k_1 and k_2 respectively and in the other calculations involving the Streeter - Phelps equation. Station 6 is only 155m from the last sampling station after the brewery effluent discharge and this is so short a distance in determining k_1 and k_2

Nevertheless, it was the longest obtainable distance.

Upon examination of Table 5.3 the extremely high reaeration rate constant (k_2) in the station 5-6 reach suggest that the oxygen is being supplied to the organic material faster than it is being taken up. Quite an unusual occurrence. There is the possibility that because of the short distance between stations 5 and 6, there might not be any sag as such; what is happening in the river is that the DO value actually remains quite constant, varying in a slight degree above and below a mean value. The organic material may not have been completely degraded and it continues to decompose at a fixed rate. This could explain why some days showed a higher BOD_5 content in station 6 than in station 5.

A Streeter- Phelps analysis on the data collected yielded a fairly comparable calculated results for DO in station 6 with the observed results. The slight deviations from the observed results could be explained from the original assumptions in the Streeter-Phelps analysis that the rivers reaeration rate is constant, the rate of reaeration and deoxygenation follow logarithmic paths and the flow and flow time are constant across the reach of the river.

It is obvious the above assumptions could not hold true. On two of the dates highlighted, the BOD_5 recorded for station 6 was higher than that recorded for station 5, hence a negative k_1 and k_2 values, see table 5.3

Assuming a combined waste discharge and using Streeter - Phelps equation for analysis showed the river in an anaerobic state in station 6 some of the time.

Combining the effluent was done with a view that the warm and alkaline effluent from the bottling hall would neutralize the cold acidic effluent from brewhouse and spoilt beers. However, this was not the case and the Streeter-Phelps analysis showed that a poorer state in the river than was the case with segregated effluents.

Assuming the brewery management obliged by the proposed effluent discharge standards (see Table 2.2) the state of the river would not be questioned. The Streeter-Phelps analysis showed a well aerated river with the least DO concentration in station 6 being 5.9 mg/l and the highest 8.1 mg/l. A weak point is hereby noticed as the river seems to be even better than was the case upstream of the brewery plant. This might be traced back to the Streeter - Phelps model used and more so the assumptions made.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS.

6.0 Introduction.

The number of polluted rivers is fast increasing in Kenya due to an increased rate of industrialisation and urbanization. The Ruiruaka river, which passes through Nairobi is a good example. Pollution of the Ruiruaka river by the brewery industry effluent has gone on a long time. The industry has never had to pretreat their waste prior to discharge to this river. Meandering channels dug long ago and aimed at retaining the effluent within a small peace of land below the plant were broken by squatters as they irrigated their small plots and the effluent eventually drained into the river. This has been going on for a long time now. Other polluting agents exist and have been seen to contribute significantly to the poor state of the river.

Surface runoff from poor soil conservation cannot also be overlooked. It has been found that even surface runoff contains significant amounts of organic pollutants and nutrients and at times it can rival sewage in terms of BOD_5 input.

The brewery effluent has induced profound changes in the chemical parameters monitored. The most prominent are DO, BOD_5, COD, dissolved solids and suspended solids. In this respect, strict pollution control measures should be undertaken, otherwise the effect of pollution if not seriously checked and other neighbouring industries decide to copy the idea of discharging untreated effluents, the effects will be felt further downstream.

6.1 Conclusions.

Based on the present studies, the following conclusions emerge.

1. The brewery effluent has induced significant changes in the chemical characteristics of the Ruiruaka river. The pollution load has caused considerable biodegradation on the river. Strict pollution control measures should be taken to address this problem.

2. There is no and has never been any treatment of the industrial effluent at the Ruiruaka brewery plant. The plant management should be enlightened on the polluting nature of their waste discharges to the Ruiruaka river and the serious need to prevent and solve the problem by pretreating before discharging to the river.

3. The Streeter - Phelps BOD-DO model used in this study may be of some use in studying tropical rivers. Though it does have its limitations and may not have been derived for the tropical regions, the calculated DO values downstream of the brewery plant agreed satisfactorily with the observed values. It could be used for continuous assessment of river quality in Kenyan rivers.

4. As the situation is now with the Tusker brewery plant discharging its industrial effluents in segregated channels, the effects, though found to be polluting the Ruiruaka river, were not as polluting as would have otherwise been if the wastewater was discharged via one channel in a combined form.

6.2 Recommendations.

Based on studies carried out, the following recommendations are worth noting:-

1. It is a fact that Kenya Breweries Ltd. have not had a waste treatment plant since it was established. To reduce the pollution load to the Ruiruaka river, it is recommended that the brewery plant should reduce its waste to an acceptable level before discharging it. Establishing a treatment plant is not an easy task especially when they have done for a long time without one. To start with, at least simple treatment techniques should be compulsory but finally a full scale treatment is inevitable and should be installed.

2. It is clear that most industries including brewery industry will not be readily willing to spend money on projects that are regarded as unproductive unless the government intervenes. Again, the technical staff entrusted with enforcing the law on river protection in this regard may not be law literate and hence a handicap. Education on both pollution awareness and the requirements in law should be used here to solve the problem.

3. Reduction of waste water qualities by recycling may be an effective approach which has an advantage of saving water. The outcome is definitely high concentrative of pollutants but this may be easily controlled since the volume of waste water is reduced. For Kenya Breweries Ltd, simple anaerobic processes may suitable be employed for the high

organic load effluent as a result of the recycling process.

4. There is no effective and enforceable laws concerning levels of industrial effluents in Kenya. The Kenya legislative does not contain a specific Act of parliament that solely deals with protection of natural water courses. River pollution control has been dealt with in bits in various statutes. A central body, for example the National Environmental Secretariat should be charged with these duties.

5. The case of soil conservation measures in the catchment areas of the Ruiruaka river is necessary if strict control of the polluting agents is to be observed. For example, the broken bottles disposal site very near the river is an additional polluting agent in that flooded effluent channels and lack of proper soil conservation in the cultivated plots have often pushed the broken bottles to the river thus adding onto the solids load. Constant monitoring of this problem should be instituted.

6. As the brewery management try to recover some of the broken glasses from the disposal site, steps should be taken to prevent further flow of the bottles into the river from flooded effluent channels or storm water. A good barrier can serve the purpose.

6.3 Suggestions for further work.

A lot has been said about the need to conserve the environment, that covers the natural waterways but not much has been done to that effect. The rivers continue to be polluted. The various sources of pollution should be traced back to their roots and

the effects of the pollution investigated. This study has attempted to do this by singling out industrial effluents from the Kenya Breweries, Ruaraka plant.

However, this is just a step towards conserving the Ruiruaka river and a lot more remains to be done:-

1. The Ruiruaka river, flows through coffee growing areas of the Kiambu district. The effects of the coffee wastes the G.S.U headquarters pond effluents and other sources downstream should be studied to reinforce this study. The comprehensive study can help give a better impression of the Ruiruaka river.

2. Other small rivers should be studied the same way before we can go to study the bigger rivers. For example, Ruiruaka, Ruiru, Ngong, Kamiti and Thiririka rivers are some of the major tributaries of the Nairobi river and are prone to intense industrial pollution by nature of their courses. A study into their pollution status would give a better picture of the Nairobi river than would be the case if Nairobi river was studied from source to mouth.

3. In an attempt to overcome the lack of a real significant oxygen sag (which was partially anticipated), a biological analysis of the selected reach is necessary to be made alongside the physico-chemical analysis already made. It is hoped that the biological analysis would at least corroborate the physicochemical analysis. This is especially important

while assuming that species differ in their ability to survive and reproduce in a given environment, and that knowledge of the inhabitants can give a picture of the habitat.

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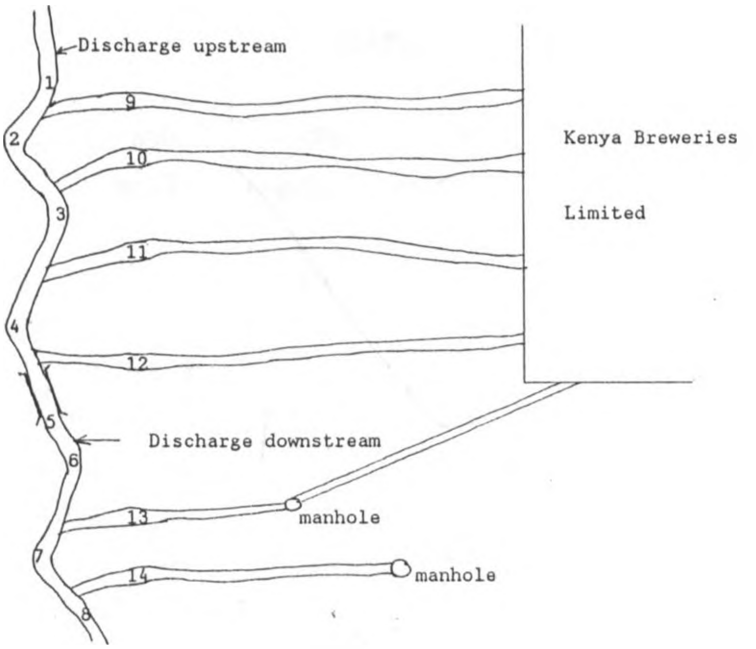
Appendix A: Tables of results of the various organic parameters analysed from the various sampling points along Ruiruaka river and the effluent discharge channels.



Sampling points on Ruiruaka river and wastewater channels

Station 1. Represent the water quality of the river before the brewery effluent.

2. River after receiving waste water from parking yard and spoilt beer channel.

3. River after receiving bottling and washing waste channel 1 (lines 1 & 2)

4. River after receiving bottling and washing waste channel 2 (lines 3 & 4)

5. River after receiving waste from BSP and brew house.

6. River 155 metres from Pt 5.

7. River after receiving domestic sewage from offices and Tusker village.

8. River after receiving sewage from Ngumba estate and Safari Park area.

9. Brewery waste from parking yard.

10. Brewery waste from bottling and washing channel 1.

11. Brewery waste from bottling and washing channel 2

12. Effluent from Barley Syrup plant, brewhouse fermenters and storage.

13. Sewage from Tusker village and offices.

14. Sewage from Ngumba estate and Safari Park areas.

STATION 1

DATE	BOD_5 (mg/l)	COD (mg/l)	DO (mg/l)	pH	TEMP (DegC)	TDS (mg/l)	TSS (mg/l)
29/10/90	1.2	3.4	7.0	7.8	26	145	54
1/11/90	0.2	1.2	7.1	7.6	25	106	42
6/11/90	8.2	11	6.2	7.6	23	105	21
9/11/90	16	34	5.4	7.3	25	112	38
13/11/90	10	30	5.5	7.2	23	123	24
17/11/90	24	57	3.5	6.9	23	153	80
23/11/90	7.5	18	6.2	7.2	24	109	67
29/11/90	10	15	6.0	6.9	25	113	29
1/12/90	15	27	5.4	6.8	26	114	14
5/12/90	15	35	5.5	7.1	24	109	67
8/12/90	19	40	3.0	7.2	26	134	32
10/12/90	25	45	2.8	7.4	27	122	49
13/12/90	12	28	3.7	7.8	27	111	21
17/12/90	7.6	30	6.3	7.0	26	101	29
20/12/90	20	33	5.1	6.7	25	114	46
24/12/90	18	41	5.2	6.8	24	109	35
28/12/90	1.3	4	6.9	7.1	26	146	27
31/12/90	35	87	2.5	7.8	25	179	72
4/01/91	3.1	13	6.7	7.9	26	126	62
9/01/91	1.4	2.9	5.0	6.9	24	132	41
12/01/91	21	26	3.9	8.2	25	112	49
16/01/91	27	50	3.5	7.1	25	121	35
21/01/91	28	68	4.2	7.5	24	152	60
24/01/91	14	39	5.6	6.7	26	155	58
28/01/91	9	15	6.1	7.2	25	124	32
31/01/91	31	52	3.9	7.3	26	106	21
5/02/91	15	32	4.8	6.6	24	113	15
8/02/91	41	77	2.5	7.0	23	181	85
12/02/91	17	46	4.3	7.8	24	132	20
15/02/91	21	57	3.9	7.1	27	165	31
20/02/91	19	42	3.5	7.6	24	121	25
AVERAGE	16	34	4.9	7.3	25	127	41

STATION 2

DATE	BOD_5 (mg/l)	COD (mg/l)	DO (mg/l)	pH	TEMP (DegC)	TDS (mg/l)	TSS (mg/l)
29/10/90	2	7	6.8	6.9	26	142	90
1/11/90	1	2	7.0	7.2	25	124	108
6/11/90	9	19	6.1	7.6	24	115	44
9/11/90	30	50	4.0	7.9	26	210	71
13/11/90	26	47	4.1	9.0	24	220	62
17/11/90	29	81	3.1	6.5	25	185	97
23/11/90	9	18	6.1	7.3	26	124	76
29/11/90	8	27	6.2	6.9	25	90	30
1/12/90	25	37	4.3	7.0	26	190	32
5/12/90	32	51	3.9	7.1	24	233	103
8/12/90	25	50	2.7	8.2	27	176	41
10/12/90	29	59	2.8	7.5	29	142	58
13/12/90	26	65	3.2	7.6	27	241	49
17/12/90	8	37	6.2	7.1	26	106	39
20/12/90	28	41	4.2	6.8	25	160	64
24/12/90	25	60	4.5	7.1	25	151	52
28/12/90	4	16	6.6	7.1	26	272	87
31/12/90	39	95	2.3	6.7	26	199	84
4/01/91	6	29	6.4	7.3	27	246	116
9/01/91	6	9	4.5	7.4	25	219	126
12/01/91	20	52	3.0	6.8	24	107	47
16/01/91	43	77	2.9	7.1	24	193	52
21/01/91	44	91	3.7	7.2	25	239	94
24/01/91	19	36	5.1	6.8	27	210	79
28/01/91	14	29	5.6	7.3	26	193	47
31/01/91	35	62	3.8	7.4	28	120	34
5/02/91	32	65	3.9	6.8	23	241	36
8/02/91	56	97	2.0	7.2	25	247	116
12/02/91	37	55	3.0	7.9	25	287	44
15/02/91	41	72	2.7	7.2	27	222	61
20/02/91	35	65	2.9	7.8	24	223	40
AVERAGE	24	48	4.3	7.3	26	188	67

STATION 3

DATE	BOD_5 (mg/l)	COD (mg/l)	DO (mg/l)	pH	TEMP (DegC)	TDS (mg/l)	TSS (mg/l)
29/10/90	4.4	13	6.6	7.2	29	182	98
1/11/90	2	6	6.8	7.1	28	126	120
6/11/90	15	38	5.5	8.3	24	192	38
9/11/90	37	67	3.9	7.2	26	259	88
13/11/90	34	58	3.8	8.7	25	218	82
17/11/90	33	99	2.5	7.7	26	210	110
23/11/90	9.9	19	6.0	7.3	26	144	88
29/11/90	26	56	4.4	7.2	27	294	75
1/12/90	28	42	4.5	8.1	29	213	26
5/12/90	37	78	3.8	7.6	24	269	105
8/11/90	28	69	2.7	6.2	27	197	47
10/12/90	31	75	2.7	6.9	29	151	61
13/11/90	29	88	2.9	7.1	28	268	51
17/12/90	18	45	4.9	7.4	28	239	67
20/12/90	22	44	4.8	6.8	26	125	51
24/12/90	26	69	4.4	6.9	25	157	51
28/12/90	5	18	6.5	7.5	26	562	104
31/12/90	49	120	2.0	7.1	26	251	101
4/01/91	6.9	33	6.3	7.2	29	280	139
9/01/91	7.8	39	3.7	7.1	25	235	128
12/01/91	30	79	2.8	7.3	29	160	70
16/01/91	57	108	2.8	6.9	29	255	74
21/01/91	49	105	3.6	7.1	30	266	105
24/01/91	25	60	4.5	6.8	29	277	104
28/01/91	20	56	5.0	7.4	28	276	71
31/01/91	39	70	3.8	7.3	29	133	26
5/02/91	45	75	3.7	6.9	28	339	45
8/02/91	72	124	2.0	7.4	27	318	149
12/02/90	49	85	2.8	8.1	28	380	58
15/02/91	57	115	2.4	7.3	28	448	84
20/02/91	47	65	2.6	7.9	29	299	62
AVERAGE	30	65	4	7	27	249	80

STATION 4

DATE	BOD_5 (mg/l)	COD (mg/l)	DO (mg/l)	pH	TEMP (DegC)	TDS (mg/l)	TSS (mg/l)
29/10/90	9.2	22	6.5	6.6	27	212	114
1/11/90	12	28	5.8	6.9	28	256	232
6/11/90	34	61	3.9	7.7	22	235	133
9/11/90	45	86	2.8	7.1	25	315	107
13/11/90	40	72	3.9	7.9	25	292	100
17/11/90	67	150	2.3	7.1	26	237	214
23/11/90	11	27	5.9	7.2	28	160	98
29/11/90	39	105	4.1	7.2	27	241	113
1/12/90	39	65	4.3	7.0	26	296	52
5/12/90	42	97	3.7	7.1	24	305	182
8/12/90	35	83	2.5	6.9	25	247	59
10/12/90	45	95	2.6	7.0	28	220	88
13/12/90	43	97	2.1	7.3	25	398	89
17/12/90	37	71	4.3	7.8	27	292	141
20/12/90	25	66	4.5	6.8	25	143	58
24/12/90	35	78	3.9	6.7	26	212	68
28/12/90	6	19	6.4	6.9	27	574	125
31/12/90	62	141	1.9	7.7	27	317	128
4/01/91	36	76	5.4	7.1	29	357	220
9/01/91	21	82	2.9	7.8	26	280	215
12/01/91	67	125	2.6	7.2	27	357	156
16/01/91	86	146	2.6	7.0	28	285	111
21/01/91	60	107	3.4	7.3	28	326	129
24/01/91	35	95	3.9	6.7	28	288	145
28/01/91	65	105	3.3	7.2	28	296	231
31/01/91	48	97	3.5	7.2	29	167	75
5/02/91	110	196	1.7	7.1	26	389	129
8/02/91	75	166	2.0	7.3	27	331	155
12/02/91	71	124	1.7	7.5	29	451	82
15/02/91	62	94	2.5	6.5	28	487	165
20/02/91	94	141	2.0	6.9	30	399	105
AVERAGE	47	94	3.5	7.2	27	302	130

STATION 5

DATE	BOD_5 (mg/l)	COD (mg/l)	DO (mg/l)	pH	TEMP Deg.C	TDS (mg/l)	TSS (mg/l)
29/10/90	20	32	4.2	7.0	26	396	187
1/11/90	30	84	4.0	6.4	24	361	300
6/11/90	62	165	2.8	7.6	23	294	159
9/11/90	85	196	2.7	7.1	25	475	202
13/11/90	200	430	0.9	9.1	24	246	380
17/11/90	140	235	2.3	6.9	26	341	372
23/11/90	16	29	5.9	7.1	25	233	143
29/11/90	110	247	2.0	7.0	26	450	319
1/12/90	50	150	3.4	7.2	25	346	47
5/12/90	86	210	1.8	7.3	24	467	399
8/12/90	85	219	2.6	7.0	26	356	181
10/12/90	120	282	1.4	6.8	25	361	252
13/12/90	61	137	2.2	7.2	25	387	146
17/12/90	62	113	3.7	6.9	25	324	239
20/12/90	80	195	2.9	6.8	24	256	184
24/12/90	62	97	3.3	7.9	24	387	163
28/12/90	7	23	6.3	8.2	24	686	145
31/12/90	87	194	3.3	7.0	25	402	198
4/01/91	74	169	3.3	6.9	26	408	412
9/01/91	135	230	1.5	6.8	25	329	395
12/01/90	89	160	2.2	7.2	26	481	208
16/01/91	166	330	1.2	7.1	28	341	215
21/01/91	85	149	2.7	6.9	25	432	193
24/01/91	75	161	3.1	6.5	25	319	285
28/01/91	301	493	1.5	6.9	25	414	286
31/01/91	59	157	2.5	7.0	26	202	65
5/02/91	200	315	2.2	7.1	26	407	200
8/02/91	81	167	1.9	7.1	27	350	185
12/02/91	85	195	2.4	6.4	26	560	141
15/02/91	450	702	0.7	6.4	26	536	664
20/02/91	125	440	2.5	6.2	27	496	127
AVERAGE	106	216	2.7	7.1	25	388	238

STATION 6

DATE	BOD_5 (mg/l)	COD (mg/l)	DO (mg/l)	pH	TEMP (DegC)	TDS (mg/l)	TSS (mg/l)
29/10/90	17	25	4.8	7.2	26	352	265
1/11/90	28	63	4.3	7.2	24	389	241
6/11/90	53	150	2.9	7.6	24	266	155
9/11/90	90	180	2.8	7.0	25	440	214
13/11/90	180	396	1.8	8.8	24	184	332
17/11/90	120	213	3.2	6.8	25	402	405
23/11/90	15	30	6.0	7.0	24	218	118
29/11/90	97	208	2.3	7.0	26	496	231
1/12/90	48	125	3.8	7.1	25	365	45
5/12/90	91	145	2.0	7.0	24	441	406
8/12/90	82	207	2.8	6.8	26	352	141
10/12/90	109	275	2.9	6.7	26	332	214
13/12/90	58	123	2.5	7.2	24	337	112
17/12/90	56	92	4.4	7.1	25	344	214
20/12/90	76	145	2.5	6.8	23	233	175
24/12/90	65	87	3.2	7.1	25	394	148
28/12/90	8.6	18	6.4	7.6	25	566	147
31/12/90	81	162	2.5	7.0	25	414	165
4/01/91	67	131	3.8	7.1	25	420	336
9/01/91	150	205	1.4	6.9	25	343	393
12/01/91	85	165	2.3	7.4	25	453	167
16/01/91	138	272	1.9	6.7	26	318	179
21/01/91	80	126	3.3	7.1	24	434	171
24/01/91	70	166	3.2	6.6	27	378	290
28/01/91	80	449	1.9	6.9	24	402	286
31/01/91	63	165	2.5	7.0	25	215	43
5/02/91	185	293	2.5	7.0	26	495	141
8/02/91	75	131	2.1	7.1	27	320	155
12/02/91	79	144	2.7	6.6	25	526	170
15/02/91	390	619	0.8	6.7	26	485	576
20/02/91	115	352	1.8	6.5	27	432	151
AVERAGE	92	189	2.9	7.1	25	379	219

STATION 7

DATE (DAYS)	BOD_5 (mg/l)	COD (mg/l)	DO (mg/l)	pH	TEMP (DegC)	TDS (mg/l)	TSS (mg/l)
29/10/90	14	38	5.2	7.0	25	306	147
6/11/90	9	48	139	2.8	7.3	23	216
13/11/90	16	186	385	2.6	6.7	25	195
29/11/90	32	92	186	3.5	7.0	25	418
5/12/90	38	89	122	3.2	6.8	24	514
10/12/90	98	231	3.8	7.0	26	356	271
17/12/90	62	72	4.8	6.7	25	415	282
24/12/90	67	82	3.8	7.4	26	335	177
31/12/90	72	110	2.7	7.5	24	475	92
9/01/91	120	162	2.0	6.5	24	342	362
16/01/91	129	284	2.0	7.2	26	325	148
24/01/91	68	175	3.2	6.6	28	387	227
31/01/91	62	164	2.6	6.9	27	335	99
8/02/91	80	127	3.1	7.2	27	321	132
12/02/91	350	546	1.0	6.9	27	517	512
AVERAGE	102	188	3.1	7.0	25	364	240

STATION 8

DATE (DAYS)	BOD_5 (mg/l)	COD mg/l)	DO mg/l)	pH	TEMP (DegC)	TDS (mg/l)	TSS (mg/l)
29/10/90	12	226	5.3	7.1	26	132	182
6/11/90	49	135	3.2	7.2	25	301	256
13/11/90	182	384	2.8	6.8	24	114	139
29/11/90	90	183	3.5	7.0	25	407	88
5/12/90	90	143	3.1	6.8	25	602	392
10/12/90	99	205	3.2	7.5	27	315	182
17/12/90	57	84	4.9	6.9	24	426	283
24/12/90	68	83	4.2	7.2	24	325	141
31/12/90	67	93	2.6	7.2	25	281	73
9/01/91	126	151	2.2	6.9	24	241	149
16/01/91	125	271	2.4	7.2	25	417	150
24/01/91	65	187	3.3	6.8	27	388	211
31/01/91	64	166	2.8	6.9	26	335	82
8/02/91	75	135	3.2	7.2	26	380	106
12/02/91	340	514	1.7	7.3	27	515	186
AVERAGE	101	197	3.2	7.1	25	333	175

WASTE FROM PARKING YARD AND SPOILT BEERS

DATE (DAYS)	BOD_5 (mg/l)	COD (mg/l)	DO (mg/l)	pH	TEMP (DegC)	TDS (mg/l)	TSS (mg/l)
29/10/90	1000	1624	1.6	5.9	25	2113	406
1/11/90	2500	4147	1.1	4.1	26	1084	540
6/11/90	1650	2661	1.7	4.3	20	1765	876
9/11/90	700	1867	2.4	5.4	25	1762	115
13/11/90	1150	2264	1.5	9.4	26	1073	455
17/11/90	5200	8625	0.5	5.2	30	7597	869
23/11/90	1750	3080	1.8	6.6	24	773	152
29/11/90	900	4304	1.6	6.2	22	4105	170
1/12/90	650	2002	1.7	4.6	26	1936	521
5/12/90	3100	5761	0.8	4.7	27	3728	624
8/12/90	920	1335	1.6	3.9	28	1714	119
10/12/90	2750	5980	1.0	4.9	29	2110	432
13/12/90	2250	5693	0.7	5.0	24	1772	292
17/12/90	1650	3973	1.4	5.0	27	1335	408
20/12/90	300	5267	0.5	6.1	26	1426	262
24/12/90	760	1267	2.8	4.5	26	1627	181
28/12/90	2050	4701	1.2	6.2	23	1409	362
31/12/90	2150	4129	1.9	8.2	29	857	421
4/01/91	2100	4938	1.2	5.5	29	531	772
9/01/91	1950	3361	1.3	3.2	30	2241	299
12/01/91	2000	4116	1.6	4.2	23	2618	562
16/01/91	2350	4793	1.1	4.5	22	1432	472
21/01/91	1750	3589	1.3	3.9	28	1971	602
24/01/91	3600	6135	0.3	5.5	28	1648	714
28/01/91	3100	5140	0.6	4.4	29	1213	432
31/01/91	2350	4145	1.1	6.7	28	947	552
5/02/91	6100	9784	0.4	8.4	20	4764	841
8/02/91	1100	3267	2.5	7.2	26	1128	521
12/02/91	4900	6525	0.5	6.3	27	3554	962
15/02/91	870	1569	2.1	5.2	29	2113	489
20/02/91	2900	5247	0.9	4.8	20	1455	535
AVERAGE	2145	4235	1.3	5.5	26	2058	483

WASTE FROM BOTTLING HALL (CHANNEL 1)

DATE (DAYS)	BOD_5 (mg/l)	COD (mg/l)	DO (mg/l)	pH	TEMP (DegC)	TDS (mg/l)	TSS (mg/l)
29/10/90	240	469	2.8	6.9	35	201	65
1/11/90	520	1113	2.7	7.2	37	321	120
6/11/90	120	180	4.5	10.4	30	148	40
9/11/90	220	579	2.9	11.0	29	294	92
13/11/90	1100	2679	1.5	9.6	30	399	130
17/11/90	420	1072	1.9	13.0	29	372	127
23/11/90	260	471	2.4	9.6	33	470	75
29/11/90	290	385	3.8	8.4	35	432	80
1/12/90	250	630	2.4	9.9	33	528	86
5/12/90	910	3043	0.5	8.7	34	958	121
8/12/90	190	423	2.6	10.3	30	486	75
10/12/90	150	412	2.8	8.3	32	321	46
13/12/90	460	996	1.8	7.8	37	652	72
17/12/90	1000	3793	1.3	8.5	34	496	92
20/12/90	900	1956	1.6	6.8	25	1004	106
24/12/90	340	422	2.5	8.2	35	397	86
28/12/90	280	420	2.3	8.4	35	426	116
31/12/90	220	332	1.5	8.7	29	487	102
4/01/91	92	256	3.2	8.5	28	506	89
9/01/91	190	376	2.7	10.7	30	517	79
12/01/91	150	312	2.8	8.7	36	496	85
16/01/91	230	639	2.5	5.9	31	706	101
21/01/91	420	872	1.9	6.9	32	649	79
24/01/91	680	1132	0.9	7.2	29	615	89
28/01/91	350	746	2.1	7.4	31	482	81
31/01/91	290	524	2.3	6.9	32	531	112
5/02/91	440	932	1.9	8.8	33	428	95
8/02/91	650	1160	1.6	10.9	30	542	86
12/02/91	1050	2130	0.8	9.7	29	1210	121
15/02/91	750	1535	1.7	8.9	28	713	89
20/02/91	470	940	1.8	8.5	34	645	75
AVERAGE	440	998	2.2	8.7	32	530	91

WASTE FROM BOTTLING HALL (CHANNEL 2)

DATE	BOD_5 (mg/l)	COD (mg/l)	DO (mg/l)	pH	TEMP (DegC)	TDS (mg/l)	TSS (mg/l)
29/10/90	130	213	2.8	6.8	28	351	92
1/11/90	570	988	1.4	6.9	35	266	64
6/11/90	90	185	4.2	7.5	25	331	108
9/11/90	240	629	2.5	11.2	27	527	128
13/11/90	1020	1445	1.5	12.7	28	612	89
17/11/90	590	1570	1.7	6.9	35	806	114
23/11/90	310	715	2.3	7.0	32	541	75
29/11/90	100	311	3.0	7.1	30	682	83
1/12/90	520	1592	1.8	7.2	29	542	132
5/12/90	1010	3118	0.8	8.1	30	1482	189
8/12/90	320	624	2.2	10.2	27	328	92
10/12/90	410	1020	1.9	8.5	29	536	52
13/12/90	350	873	2.1	7.9	34	776	49
17/12/90	190	775	1.6	6.9	30	559	106
20/12/90	950	1288	1.2	6.3	26	802	51
24/12/90	260	669	2.4	8.5	27	621	96
28/12/90	590	1221	1.7	8.0	25	286	78
31/12/90	190	417	2.6	7.8	28	561	106
4/01/91	100	370	2.8	7.9	29	921	82
9/01/91	360	726	1.6	8.0	33	497	89
12/01/91	71	140	3.5	10.2	32	572	76
16/01/91	390	957	2.0	5.0	29	621	126
21/01/91	520	1070	1.6	6.9	27	427	71
24/01/91	230	372	2.5	7.1	27	987	95
28/01/91	490	715	1.8	8.3	30	728	75
31/01/91	320	757	2.2	7.5	33	607	125
5/02/91	650	1865	1.6	8.9	34	856	104
8/02/91	570	1045	1.7	9.3	29	672	110
12/02/91	1160	2472	0.7	10.6	30	842	128
15/02/91	850	1340	1.6	7.7	28	819	85
20/02/91	510	955	1.8	8.1	35	615	89
AVERAGE	454	982	2.0	8.1	30	638	95

WASTE FROM BREWHOUSE & BSP

DATE	BOD_5 (mg/l)	COD (mg/l)	DO (mg/l)	pH	TEMP (DegC)	TDS (mg/l)	TSS (mg/l)
29/10/90	1300	2631	1.5	4.5	29	1469	1502
1/11/90	3400	5540	1.4	4.4	21	450	878
6/11/90	4200	7455	1.2	4.1	27	1496	6515
9/11/90	5900	8629	0.6	5.3	30	1728	926
13/11/90	12000	25660	0.0	6.2	23	6560	11465
17/11/90	7200	12078	0.2	4.9	22	1346	1062
23/11/90	3200	6696	0.9	5.3	25	831	1404
29/11/90	7500	12595	1.1	7.7	29	4783	6672
1/12/90	1000	2031	1.6	5.4	27	1046	3218
5/12/90	4100	6632	0.6	4.8	25	1529	1042
8/12/90	9400	14348	0.0	4.9	22	1332	921
10/12/90	4500	7676	1.3	5.3	21	1841	6218
13/12/90	1900	2822	1.2	7.0	27	1792	1521
17/12/90	2000	5230	1.5	6.2	25	2546	322
20/12/90	7600	11084	0.2	5.5	26	3279	1324
24/12/90	850	1715	1.1	4.4	30	2114	928
28/12/90	2500	6249	0.7	4.9	24	916	1480
31/12/90	2550	4798	0.6	7.9	23	2229	628
4/01/91	3900	8496	0.9	5.1	25	3248	1426
9/01/91	7200	13270	0.1	3.0	28	1536	1061
12/01/91	2400	5961	0.3	4.1	29	1328	1209
16/01/91	6200	11969	0.2	5.5	30	1481	721
21/01/91	2500	3937	0.6	4.4	23	997	831
24/01/91	4300	6745	0.7	4.9	30	1521	948
28/01/91	12000	20456	0.0	4.8	25	6713	7649
31/01/91	3600	5632	0.9	6.9	20	1819	872
5/02/91	3000	5087	1.0	7.2	27	1649	1729
8/02/91	950	2100	1.6	6.9	29	2446	3521
12/02/91	2600	4935	0.7	5.8	23	2019	1585
15/02/91	11000	18340	0.0	6.1	26	4542	6345
20/02/91	4500	6625	0.6	4.2	28	1446	1756
AVERAGE	4685	8304	0.8	5.4	26	2195	2506

SEWAGE FROM TUSKER VILLAGE & OFFICES

DATE	BOD_5 (mg/l)	COD (mg/l)	DO (mg/l)	pH	TEMP (DegC)	TDS (mg/l)	TSS (mg/l)
29/10/90	305	439	2	6.5	24	521	129
6/11/90	160	328	2.7	6.7	26	352	521
13/11/90	450	726	1.4	7.1	22	583	841
29/11/90	290	622	2.3	7.2	28	435	473
5/12/90	320	626	1.8	7.3	24	795	592
10/12/90	89	157	3.5	6.7	26	436	361
17/12/90	200	562	2.6	6.7	26	1348	625
24/12/90	150	239	2.8	7.1	30	276	497
31/12/90	290	413	1.9	7.2	26	621	170
9/01/91	225	346	2.3	6.9	28	481	321
16/01/91	175	309	2.3	7.8	26	502	196
24/01/91	140	315	2.8	6.5	26	531	431
31/01/91	470	834	1.3	6.8	25	812	825
8/02/91	305	581	2.3	7.5	27	431	292
15/02/91	250	431	2.4	7.2	28	595	355
AVERAGE	255	462	2.3	7.0	26	581	442

SEWAGE FROM NGUMBA AND SAFARI PARK AREAS

DATE	BOD_5 (mg/l)	COD (mg/l)	DO (mg/l)	pH	TEMP (DegC)	TDS (mg/l)	TSS (mg/l)
29/10/90	76	126	3.6	7.1	25	136	121
6/11/90	192	409	2.5	7.4	25	482	480
13/11/90	120	229	2.9	7.0	23	89	76
29/11/90	140	311	1.8	7.1	27	448	102
5/12/90	125	314	2.9	6.8	25	621	106
10/12/90	220	346	1.9	8.2	26	207	95
17/12/90	215	389	2.6	7.1	25	627	652
24/12/90	130	230	2.9	6.9	29	410	153
31/12/90	170	316	2.7	6.5	27	126	110
9/01/91	95	296	3.3	7.1	27	262	82
16/01/90	240	446	2.5	7.2	25	981	479
24/01/91	180	415	2.7	7.4	27	348	115
31/01/90	150	362	2.5	6.9	26	255	97
8/02/91	200	442	2.6	7.1	26	431	105
15/02/91	240	505	2.3	8.1	27	310	52
AVERAGE	166	342	2.6	7.2	26	382	188

COMBINED EFFLUENTS (STATIONS 9,10,11,12)

DATE	BOD_5 (mg/l)	COD (mg/)	DO (mg/l)	pH	TDS (mg/l)	TSS (mg/l)
1/11/90	1900	2819	1.4	6.3	662	514
9/11/90	2250	3621	1.2	9.9	921	445
23/11/90	1600	2515	1.6	7.2	2215	362
1/12/90	850	1424	2.0	6.4	1132	816
8/12/90	3450	6245	1.0	5.8	1213	379
13/12/90	1450	2526	1.7	6.7	1162	456
20/12/90	3850	7019	0.9	6.2	1835	462
28/12/90	1950	3245	1.5	6.7	1137	486
4/1/91	2100	3631	1.3	6.9	1365	456
12/1/91	1550	3063	1.7	6.7	1147	621
21/1/91	1250	2412	1.8	5.6	1159	442
28/1/91	4200	7465	0.6	6.5	2339	2561
5/2/91	2200	3935	1.3	8.1	1850	581
12/2/91	2600	4324	1.2	6.6	2002	836
20/2/91	1970	3634	1.5	6.2	948	721
AVERAGE	2211	3859	1.4	6.8	1406	676

Appendix B : Graphs of variations in parameters monitored.

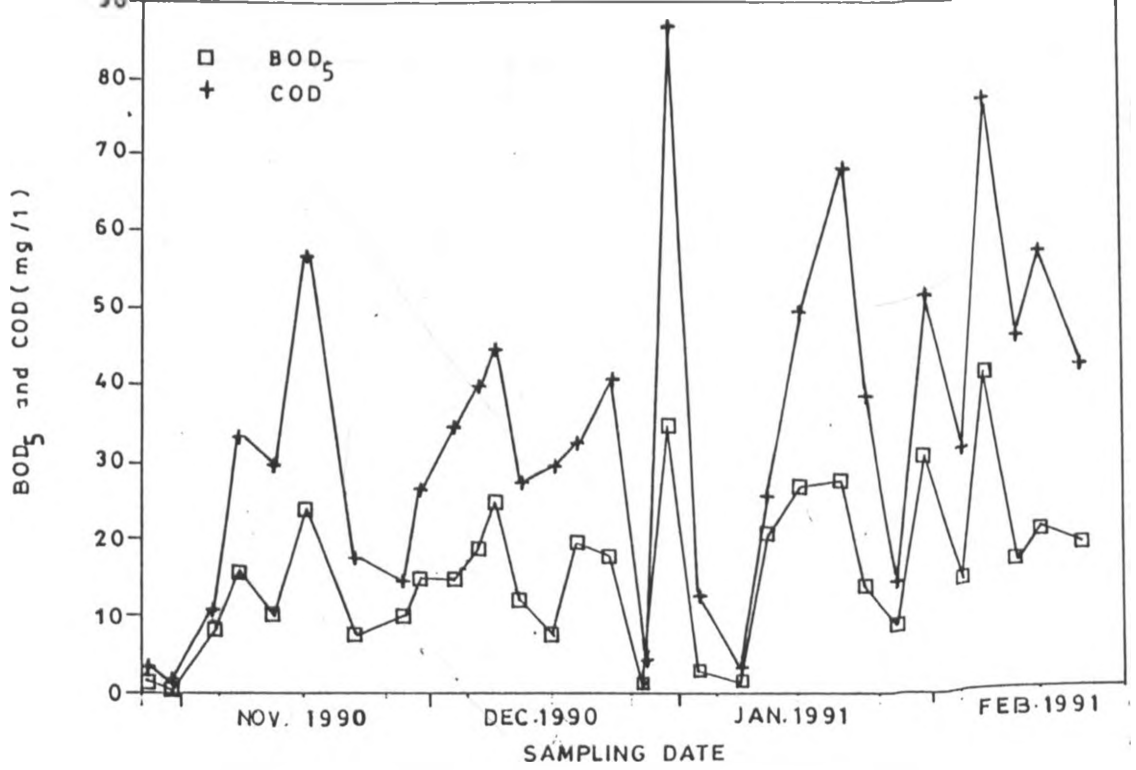


Fig. 1 VARIATION OF BOD_5 AND COD FOR STATION 1

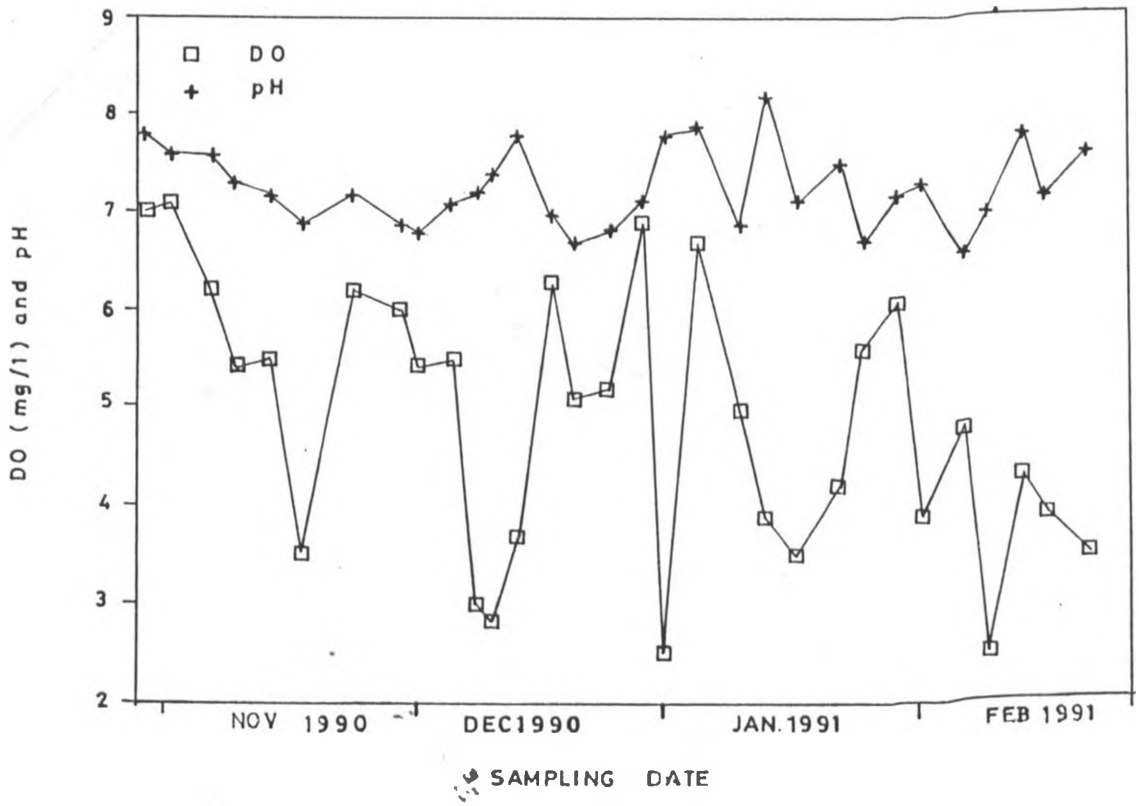


Fig. 2 VARIATION OF DO AND pH FOR STATION 1

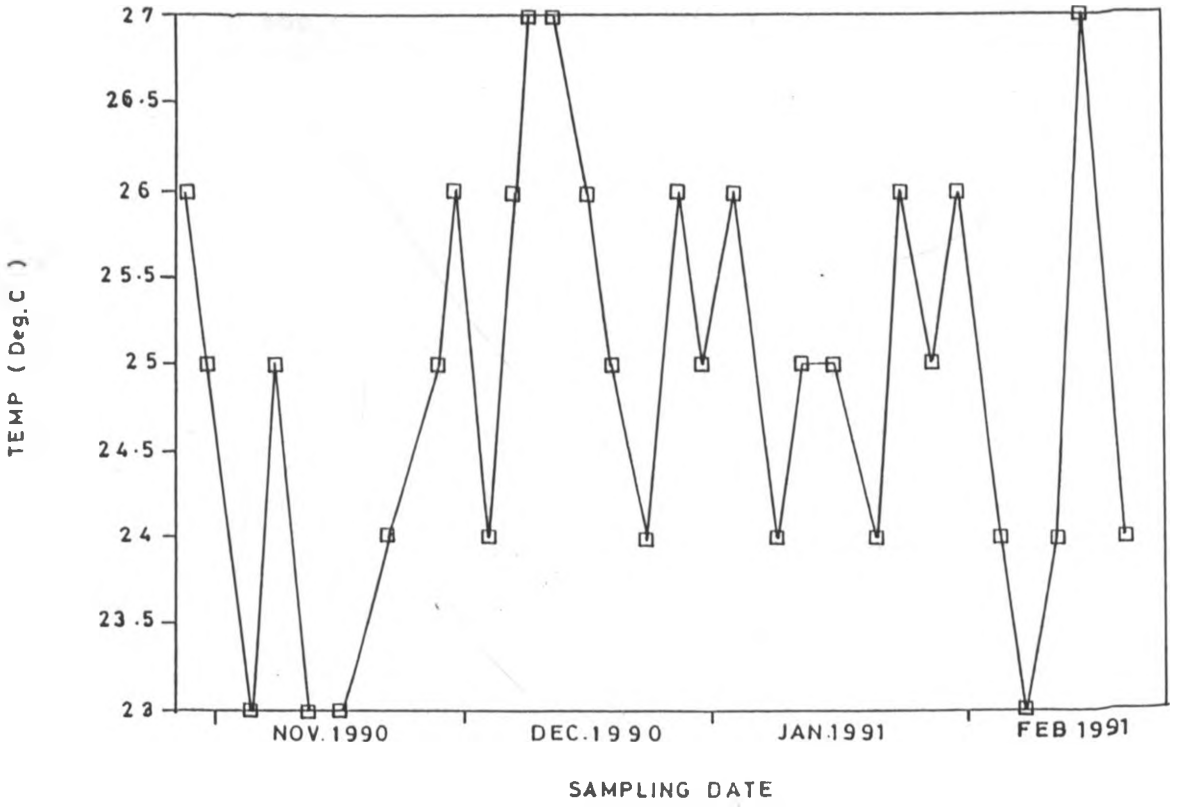


Fig. 3 VARIATION IN TEMPERATURE FOR STATION 1

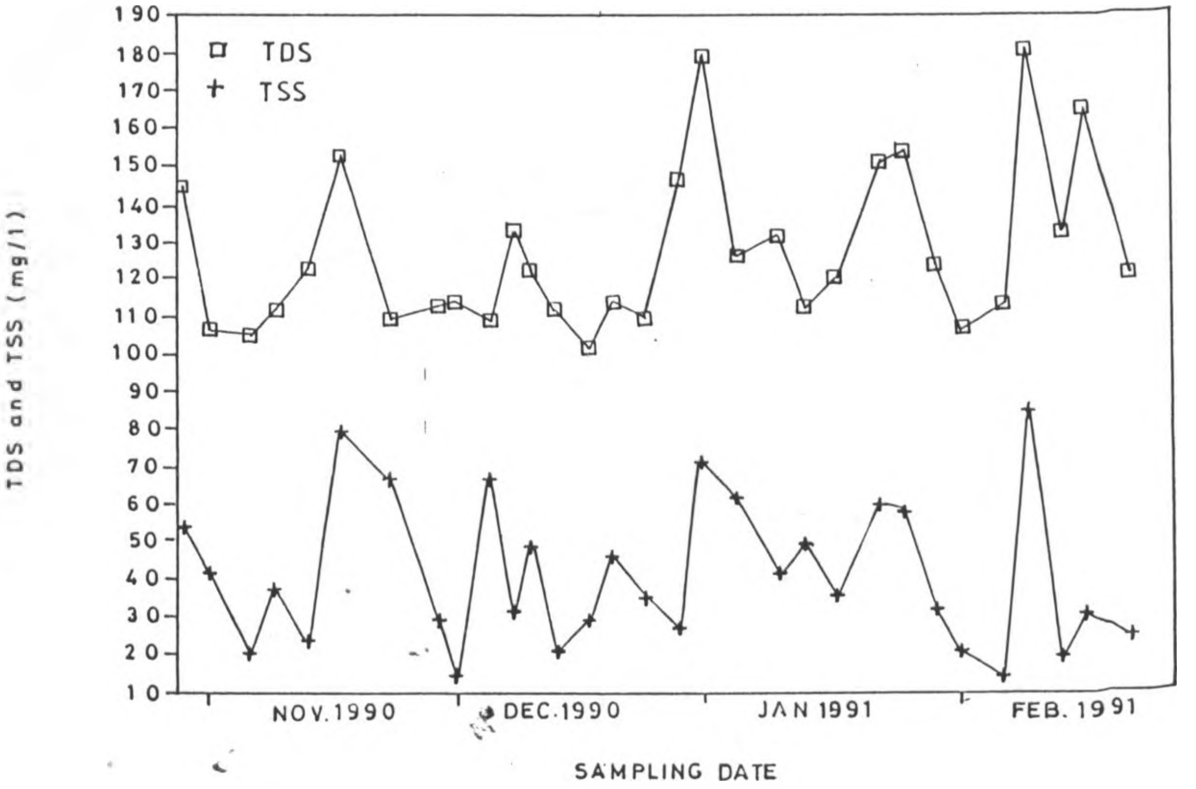


Fig 4 VARIATION IN TDS AND TSS FOR STATION 1

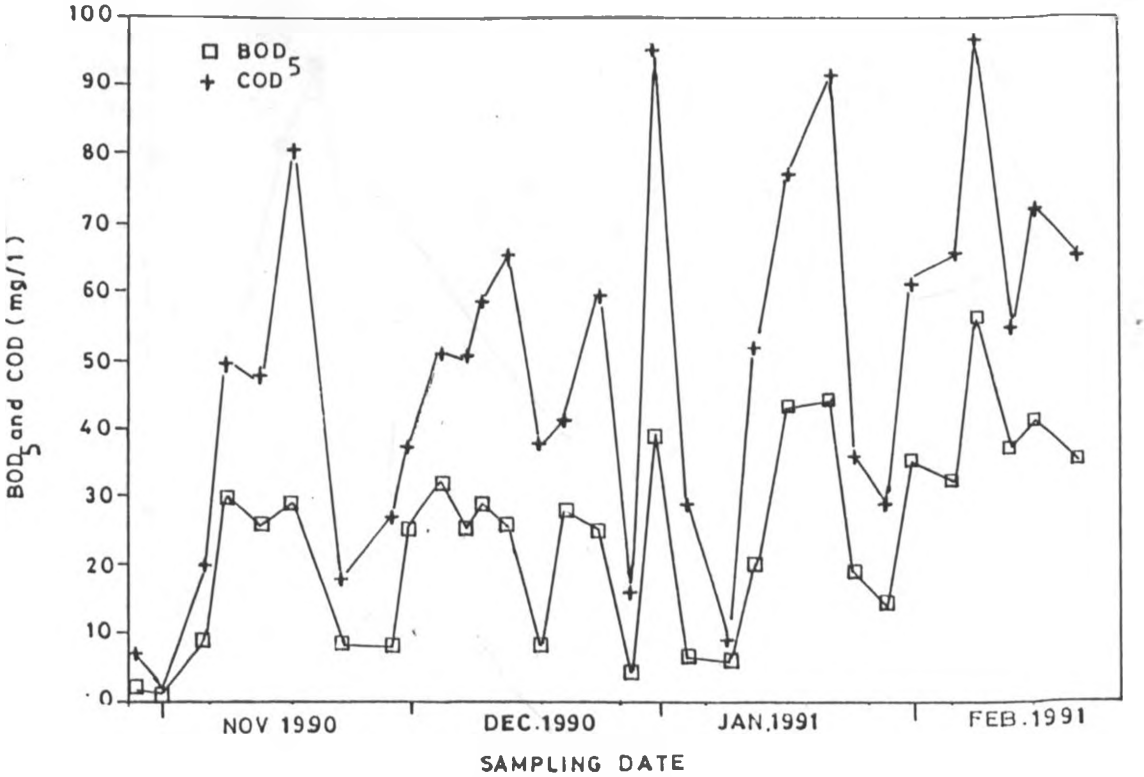


Fig. 5 VARIATION IN BOD_5 AND COD FOR STATION 2

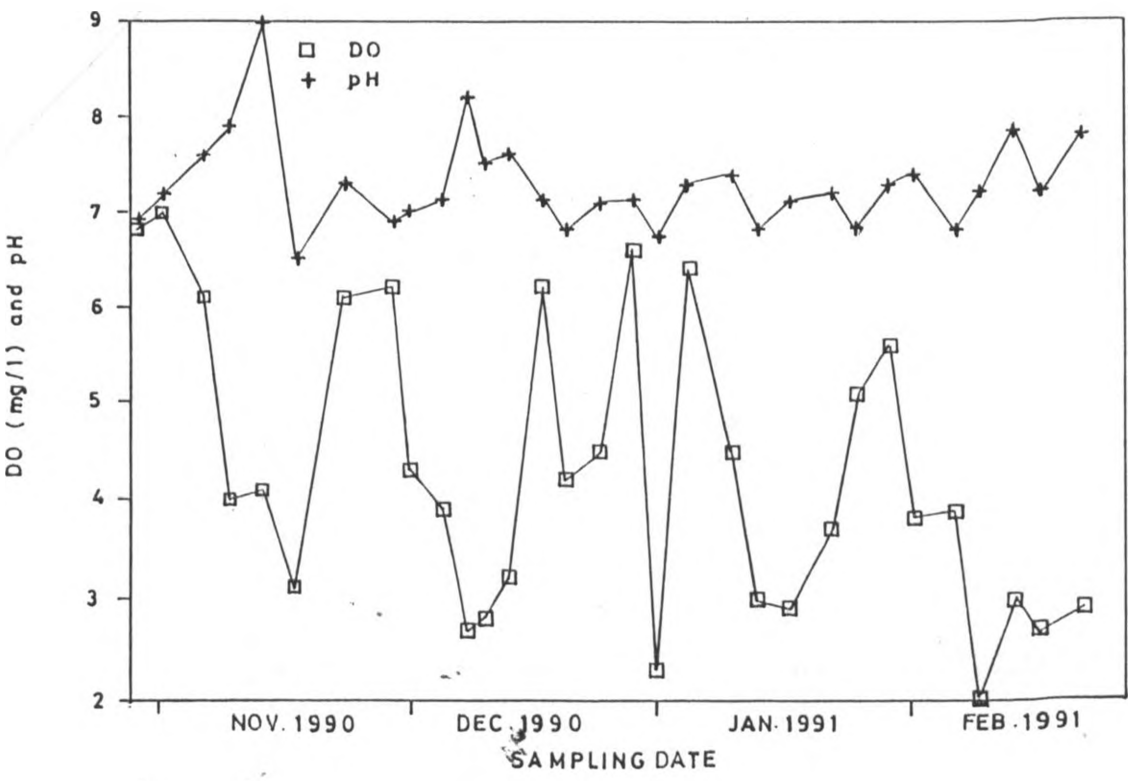


Fig 6 VARIATION IN DO AND pH FOR STATION 2

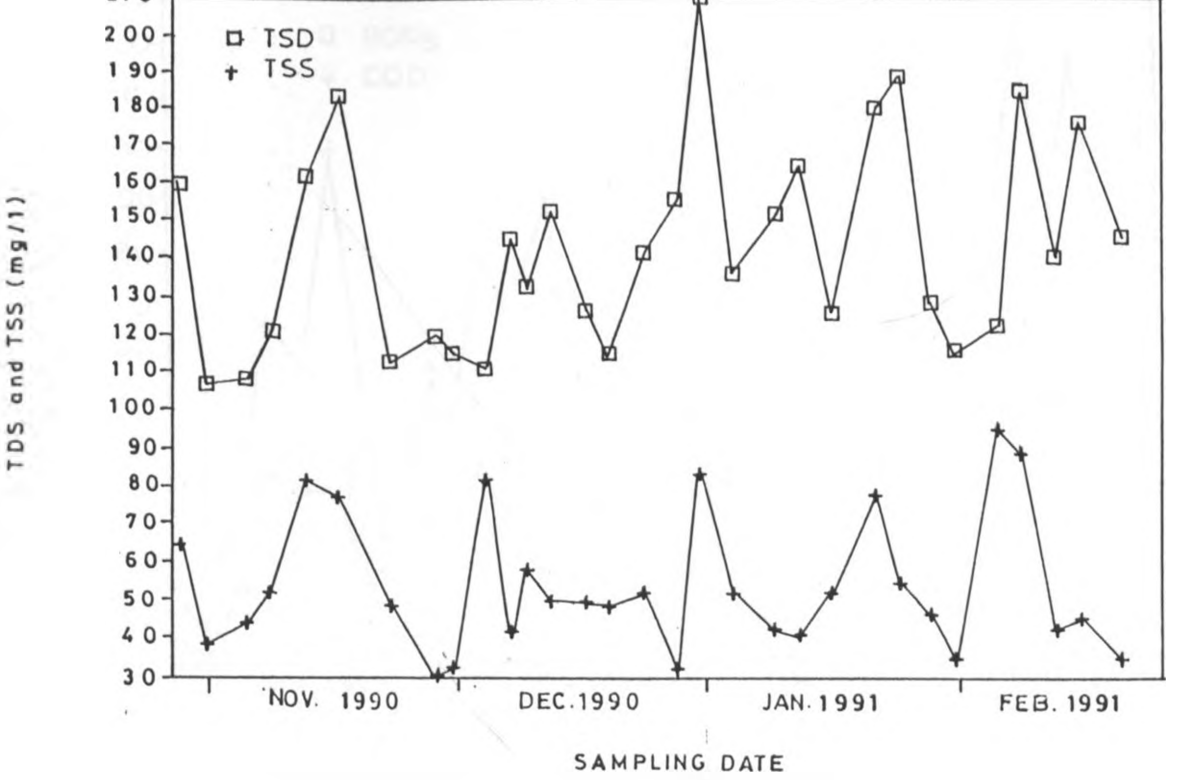


Fig. 7 VARIATION IN TDS AND TSS FOR STATION 2

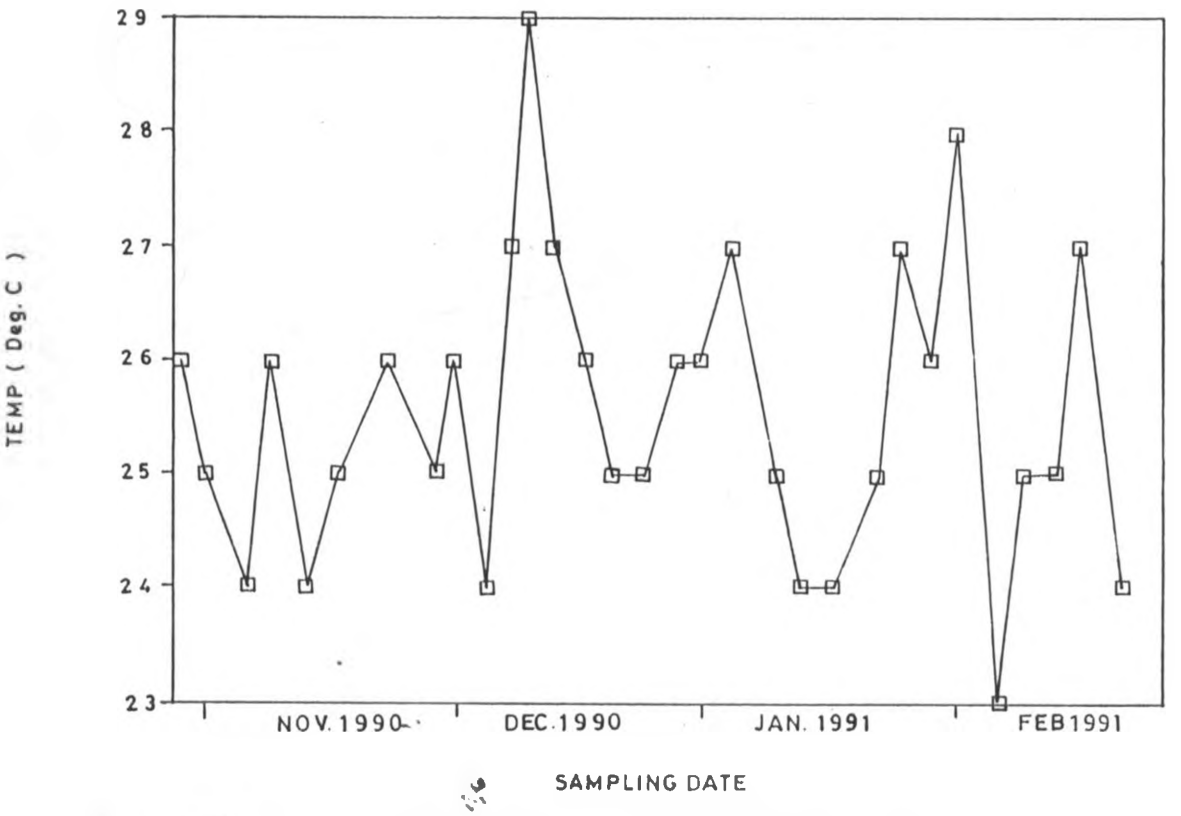


Fig. 8 VARIATION IN TEMPERATURE FOR STATION 2

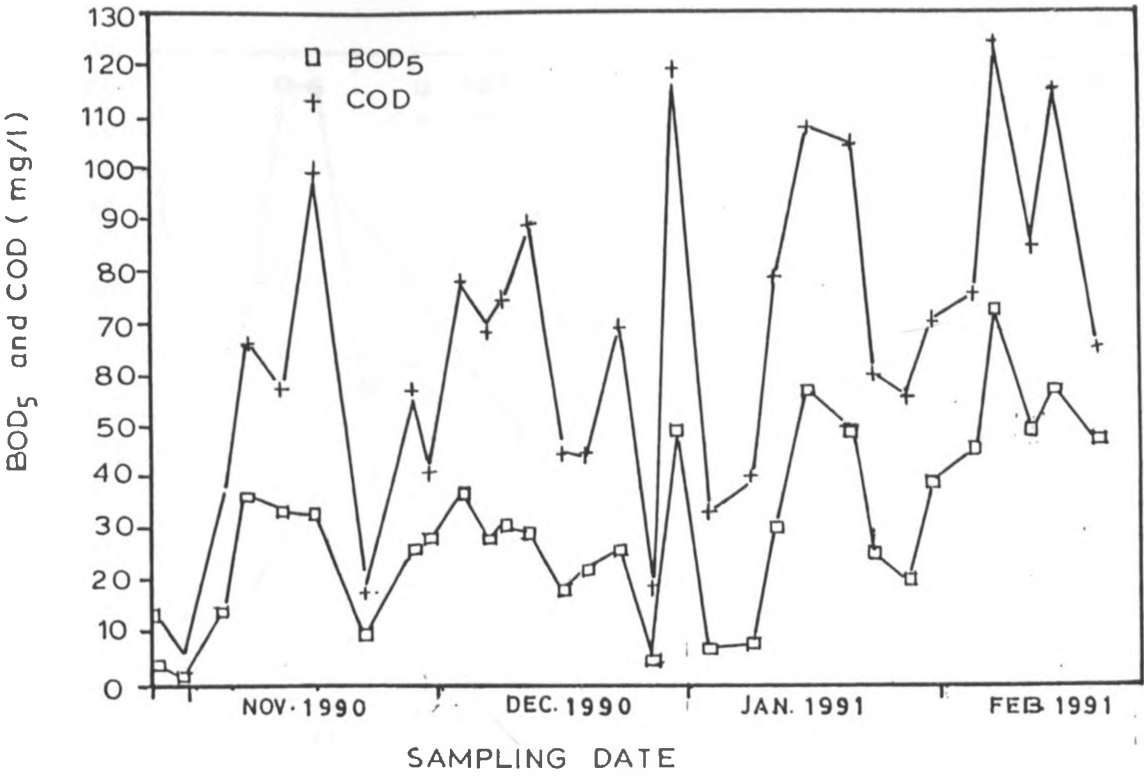


Fig 9 VARIATION IN BOD_5 AND COD FOR STATION 3

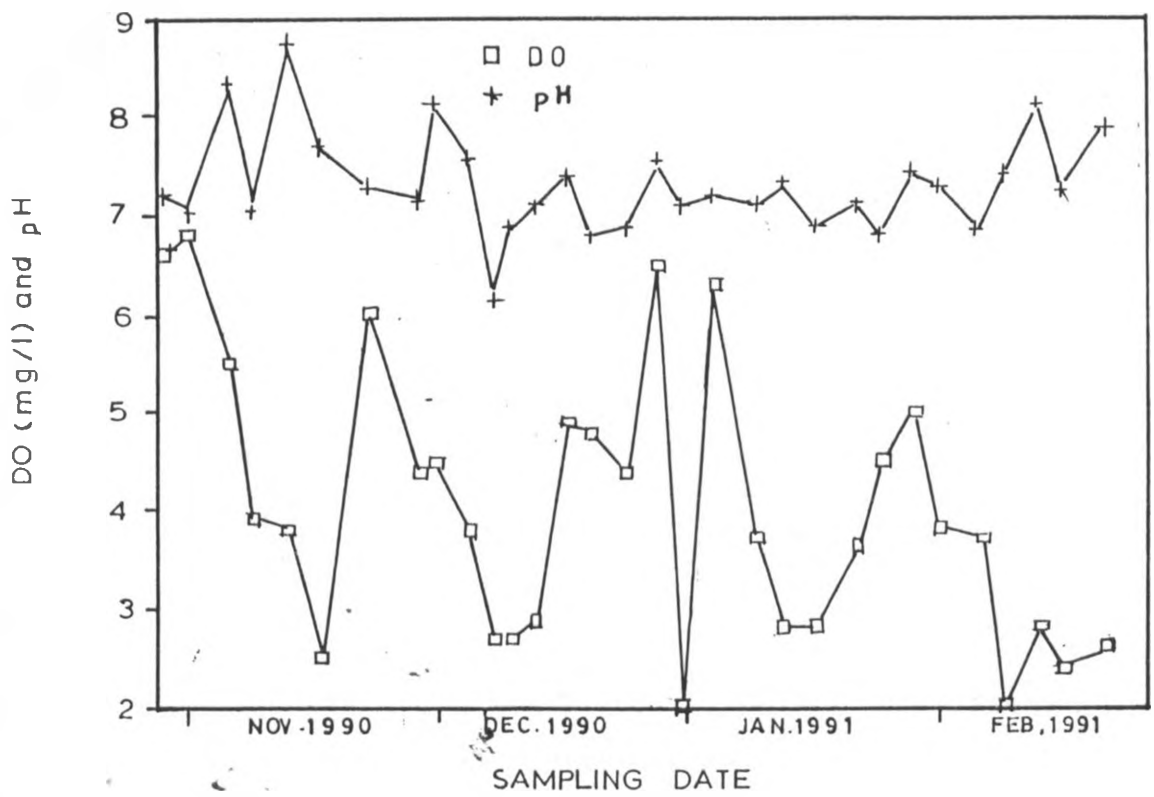


Fig. 10 VARIATION IN DO AND pH FOR STATION 3

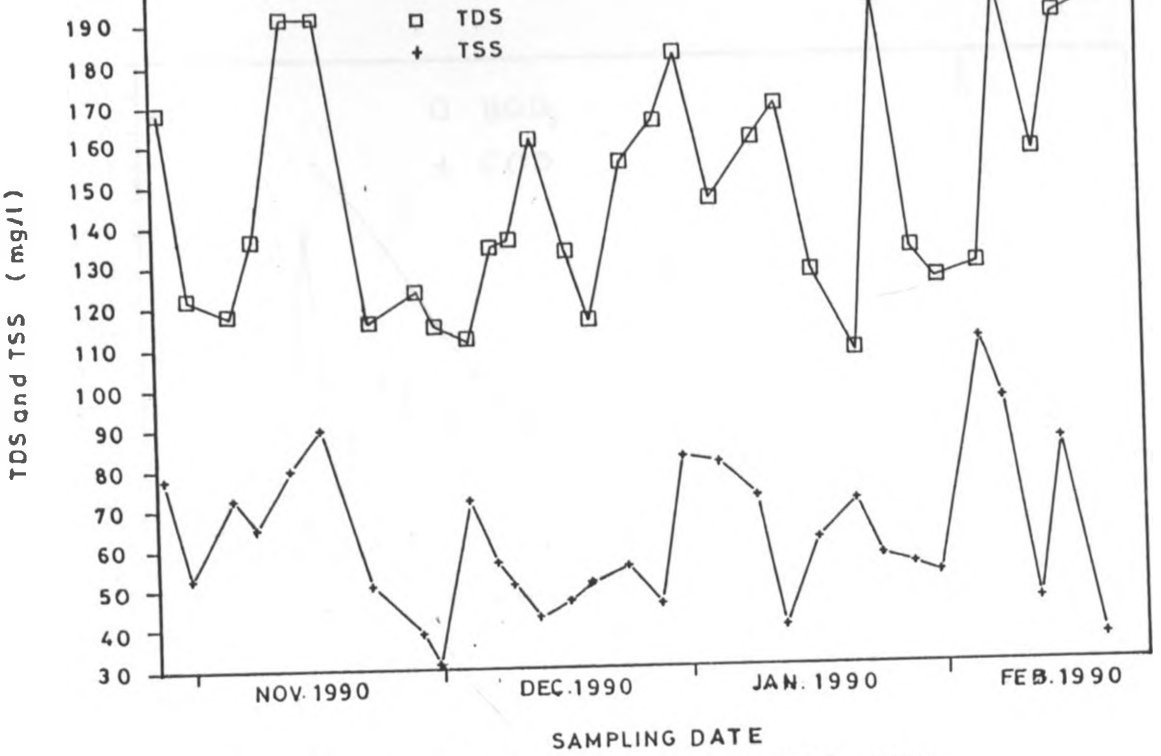


Fig. 11 VARIATION IN TDS AND TSS FOR STATION 3

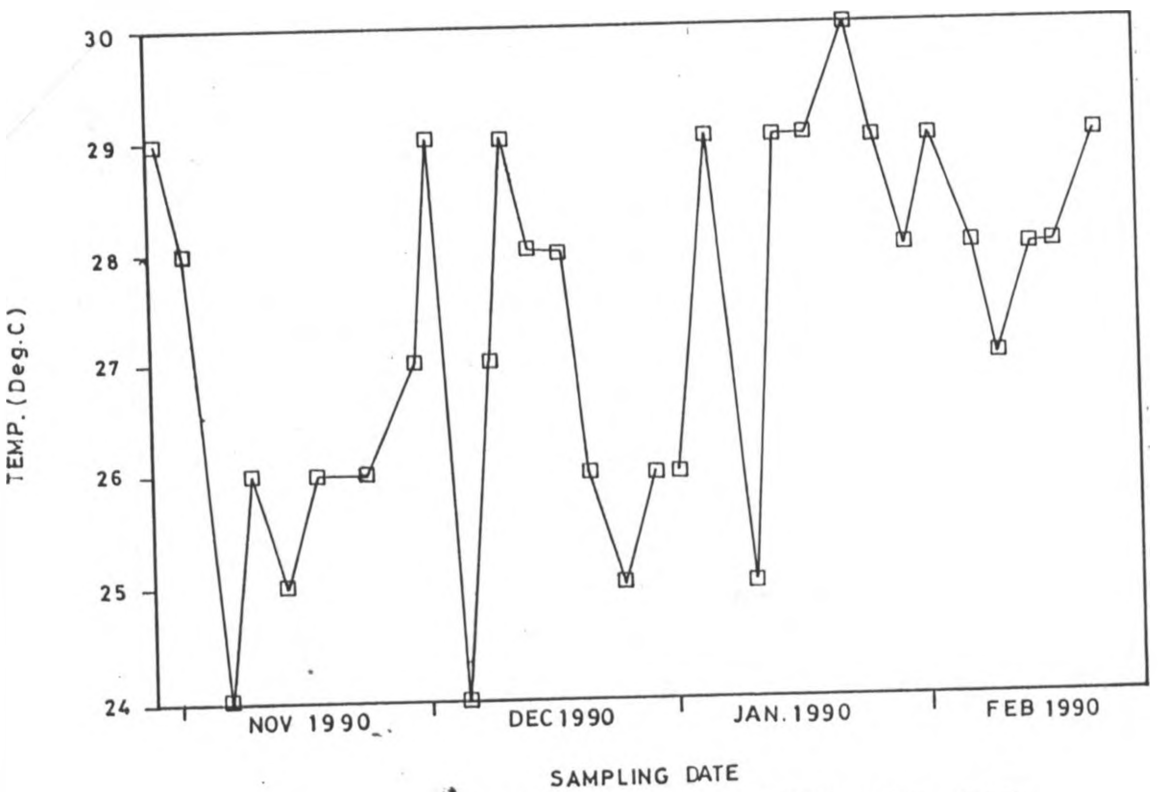


Fig. 12 VARIATION IN TEMPERATURE FOR STATION 3

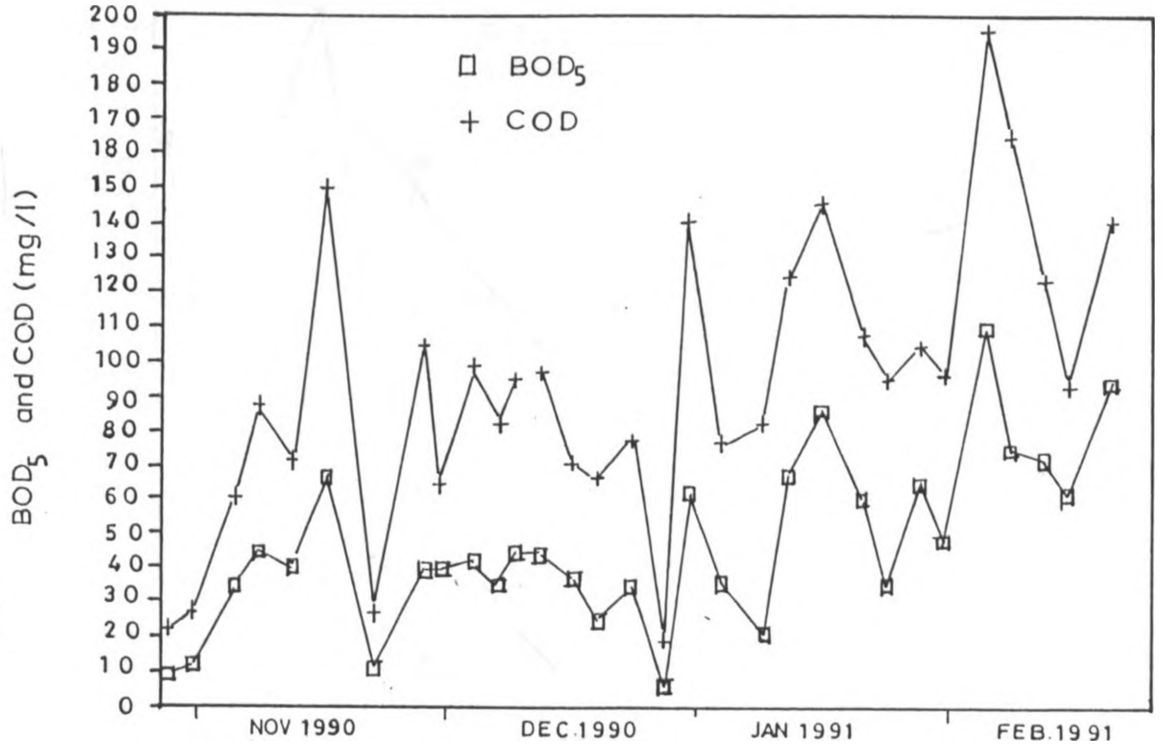


Fig. 13 VARIATION IN BOD_5 AND COD FOR STATION 4

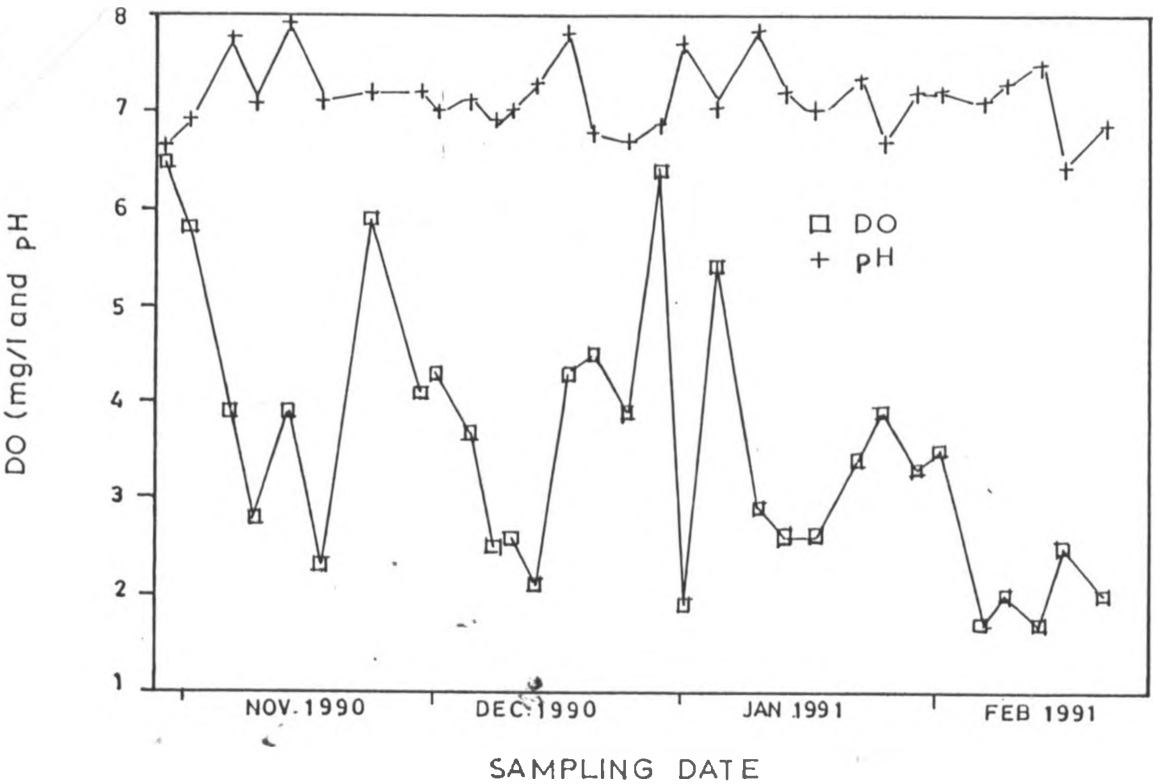


FIG. 14 VARIATION IN DO AND pH FOR STATION 4

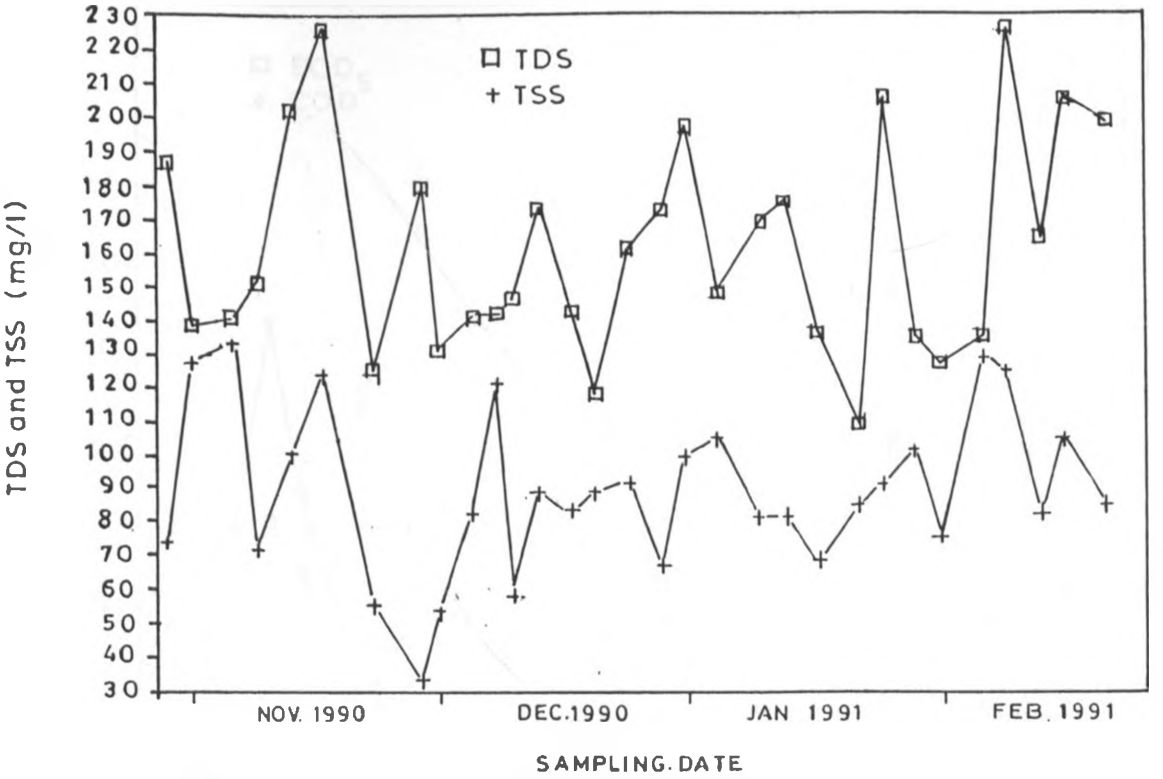


Fig.. 15 VARIATION IN TDS AND TSS FOR STATION 4

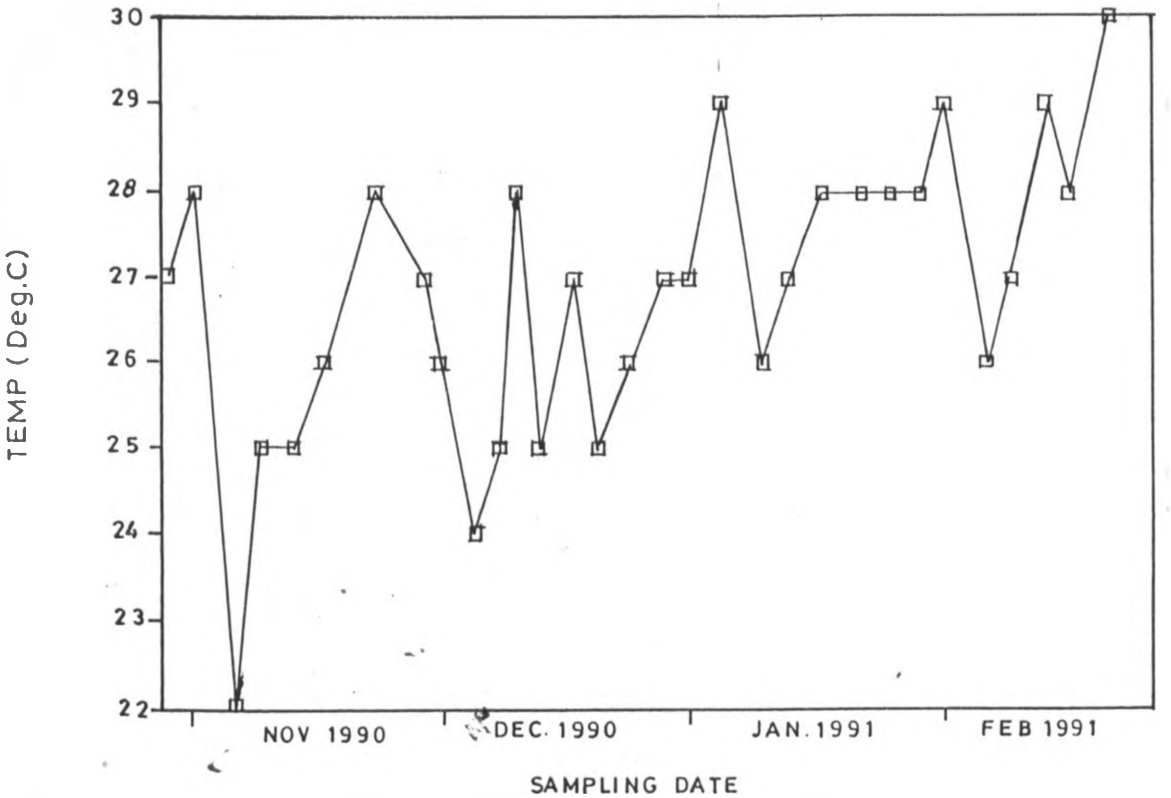


Fig 16 VARIATION IN TEMPERATURE FOR STATION 4

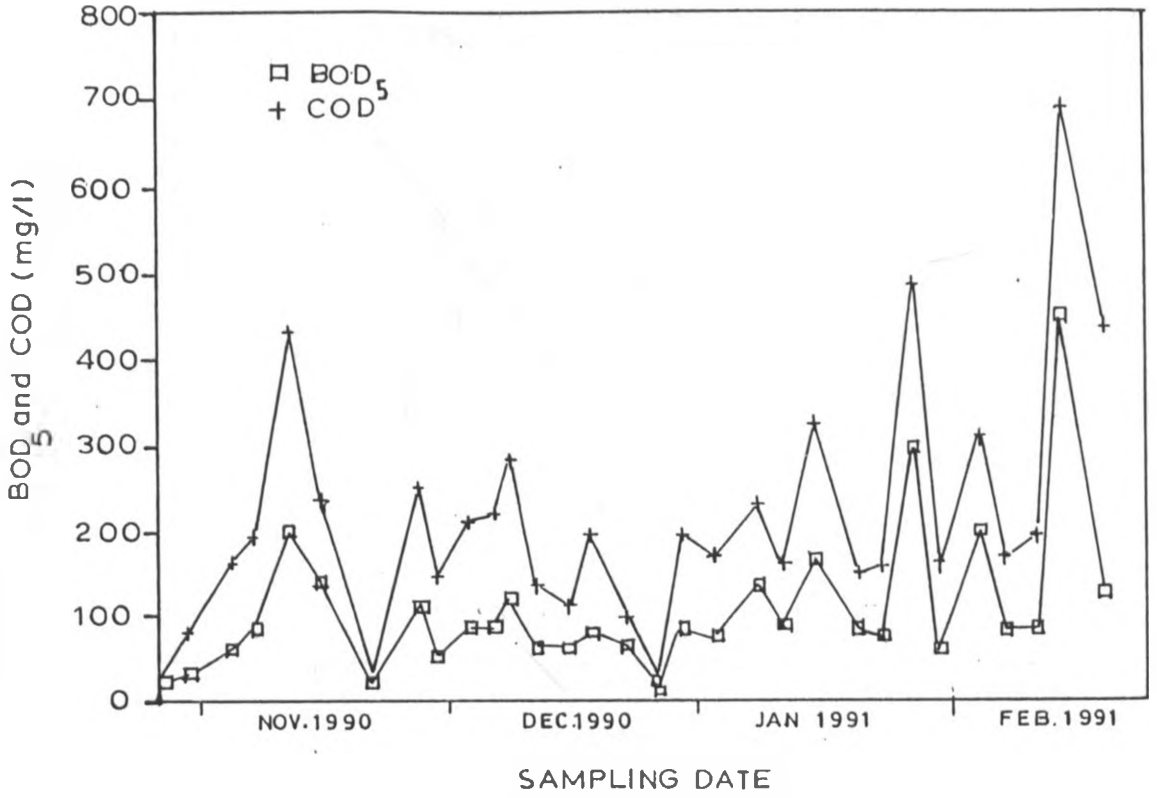


Fig 17 VARIATION IN BOD_5 AND COD FOR STATION 5

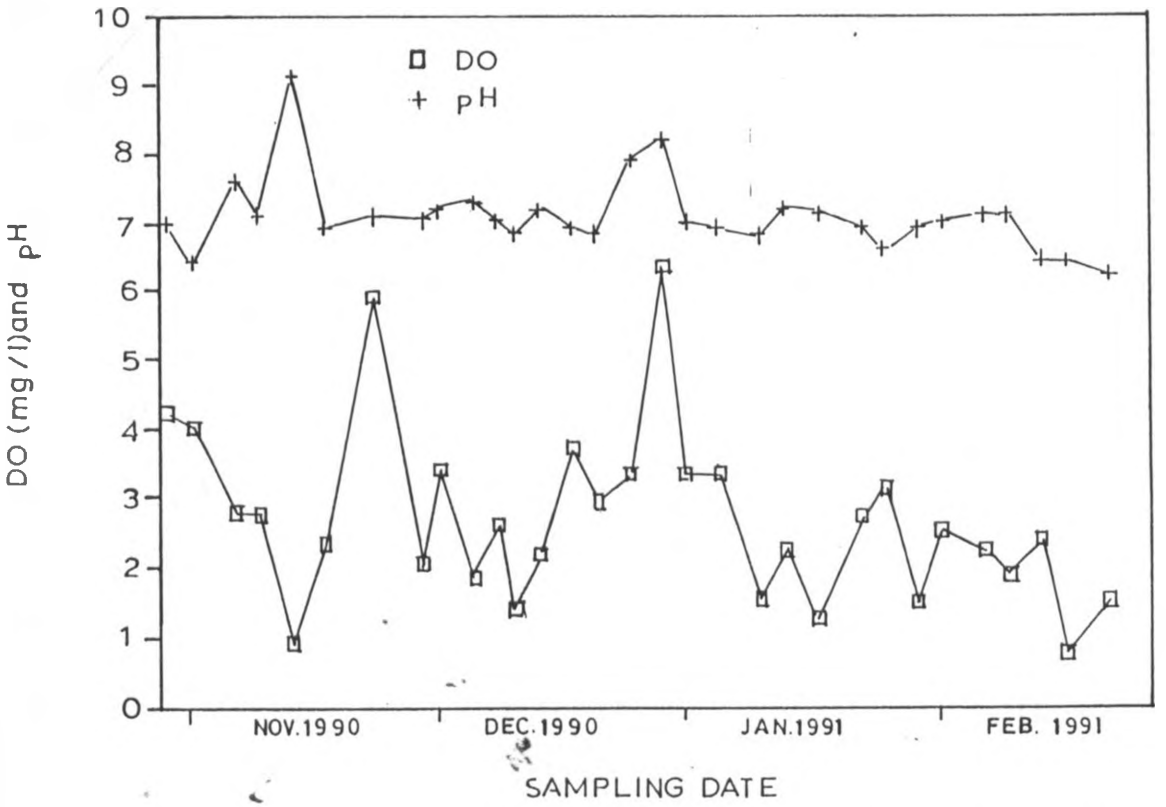


Fig. 18 VARIATION IN DO AND pH FOR STATION 5

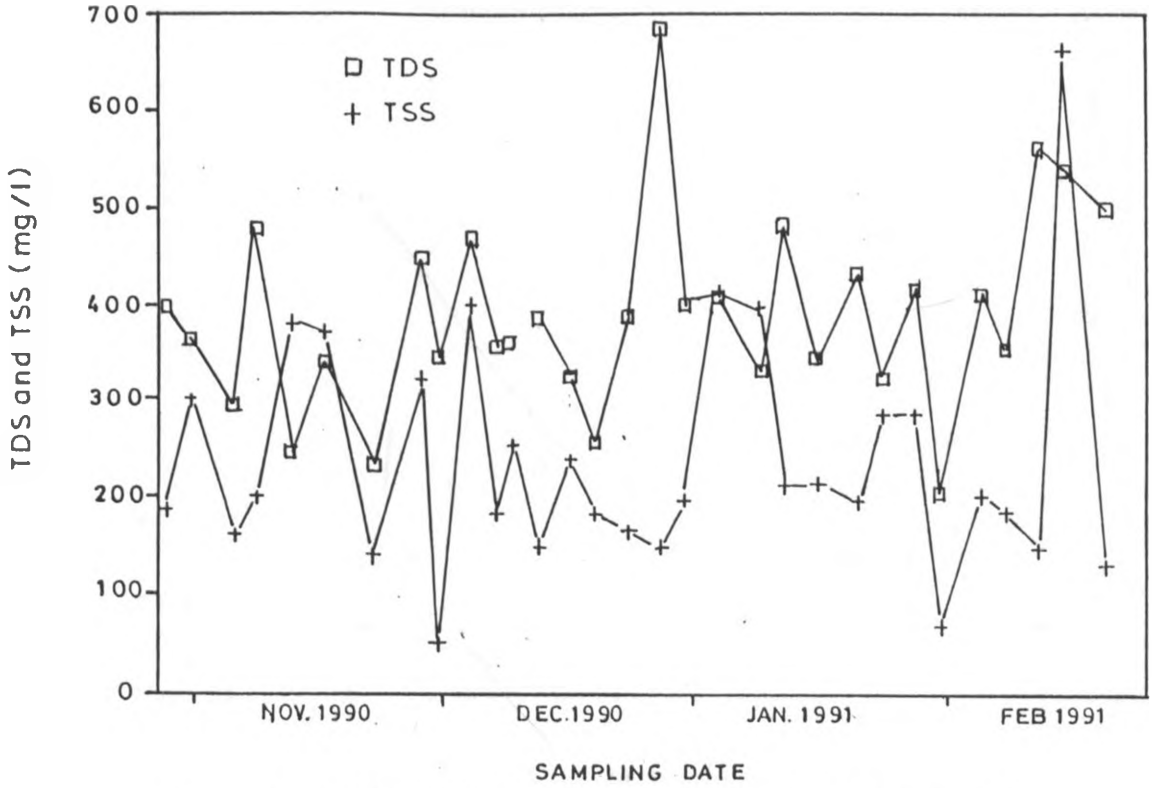


Fig. 19 VARIATION IN TDS AND TSS FOR STATION 5

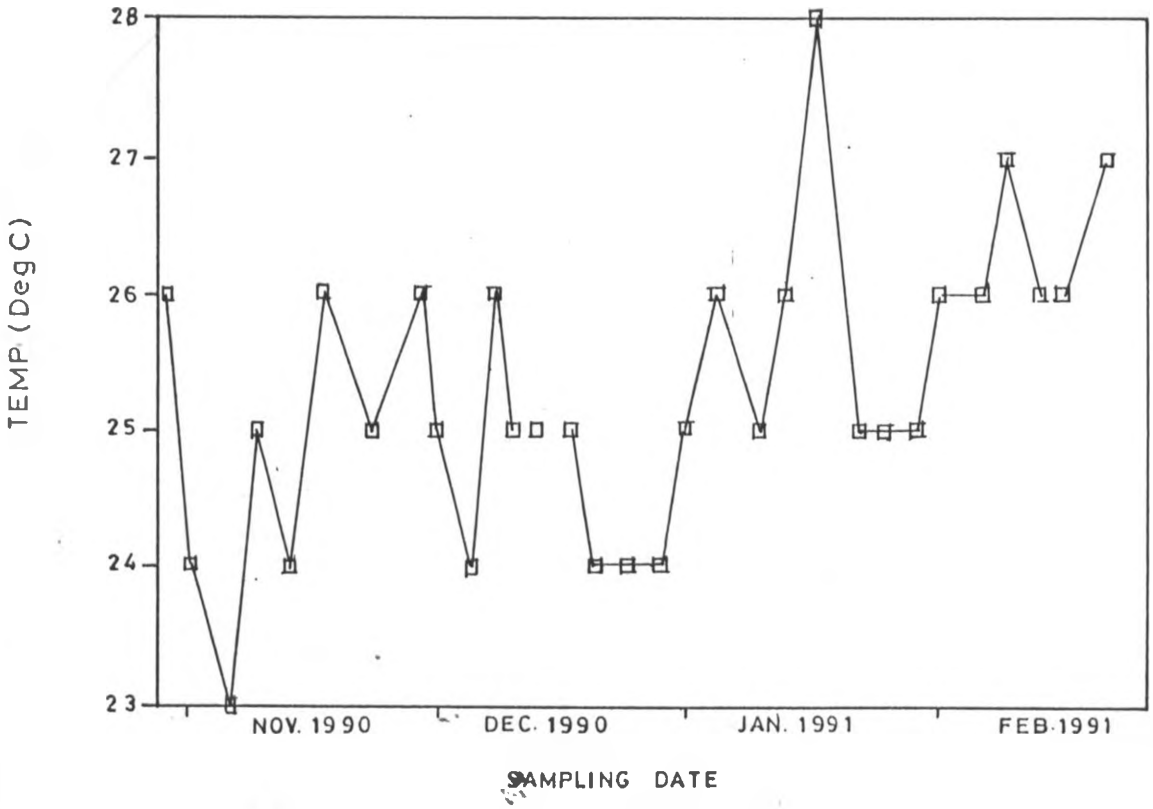


Fig. 20 VARIATION IN TEMPERATURE FOR STATION 5

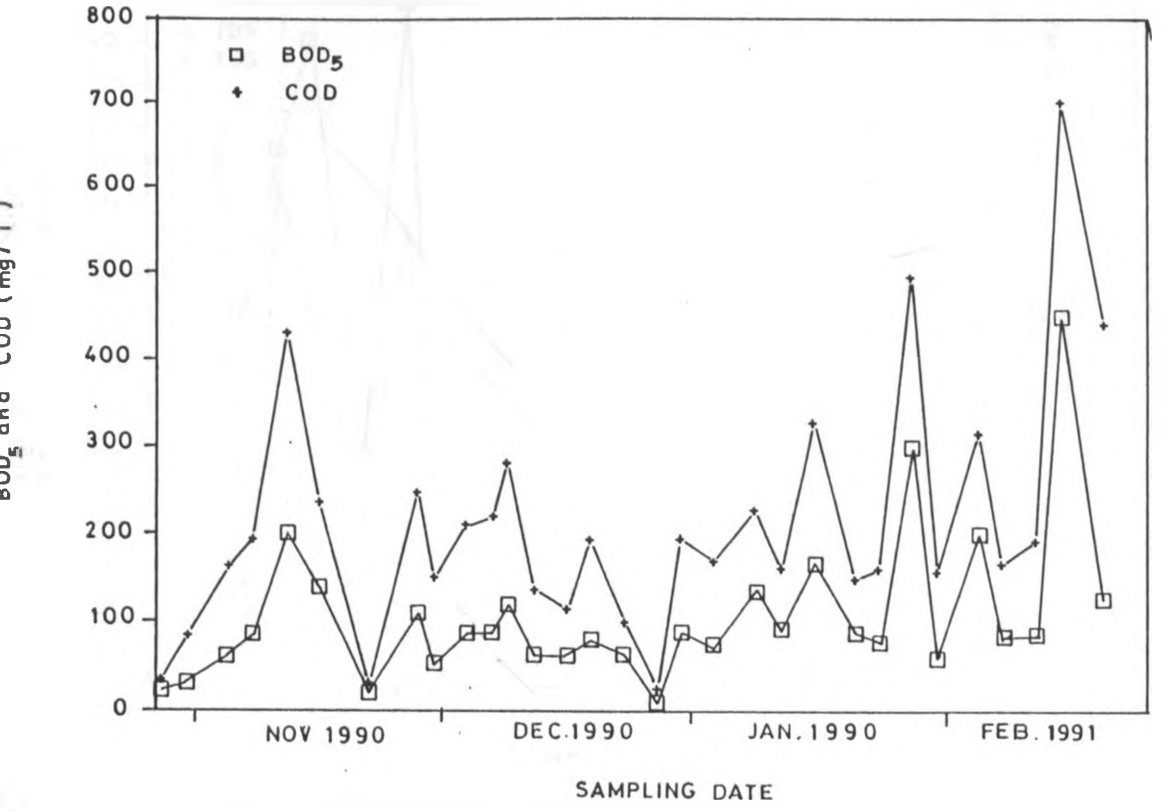


Fig 21 VARIATION IN BOD_5 AND COD FOR STATION 6

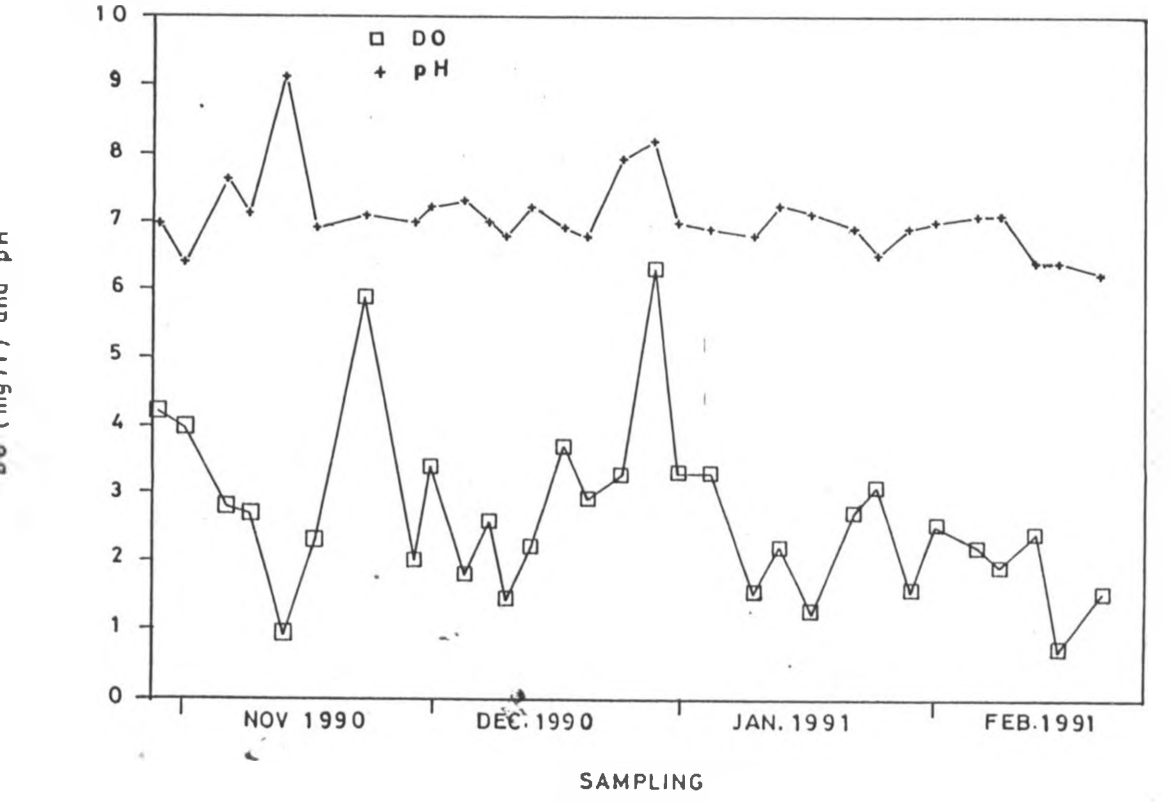


Fig. 22 VARIATION IN DO AND pH FOR STATION 6

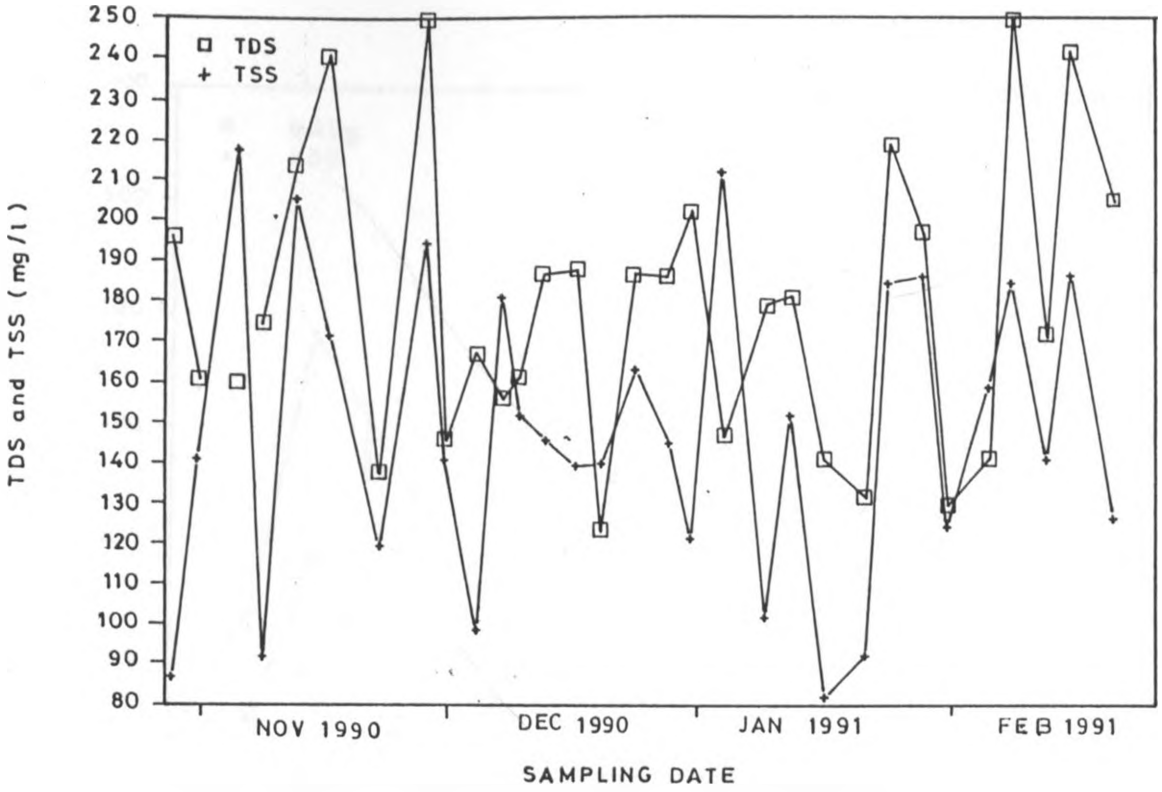


Fig. 23 VARIATION IN TDS AND TSS FOR STATION 6

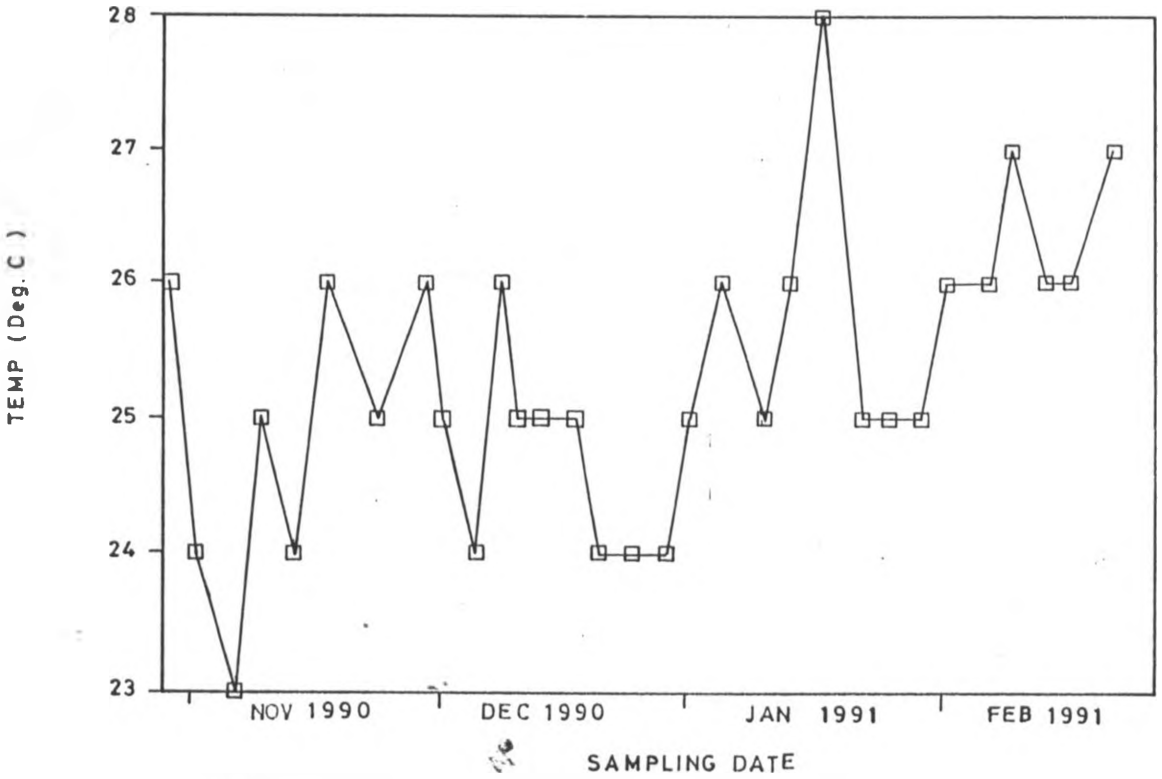


Fig. 24 VARIATION IN TEMPERATURE FOR STATION 6

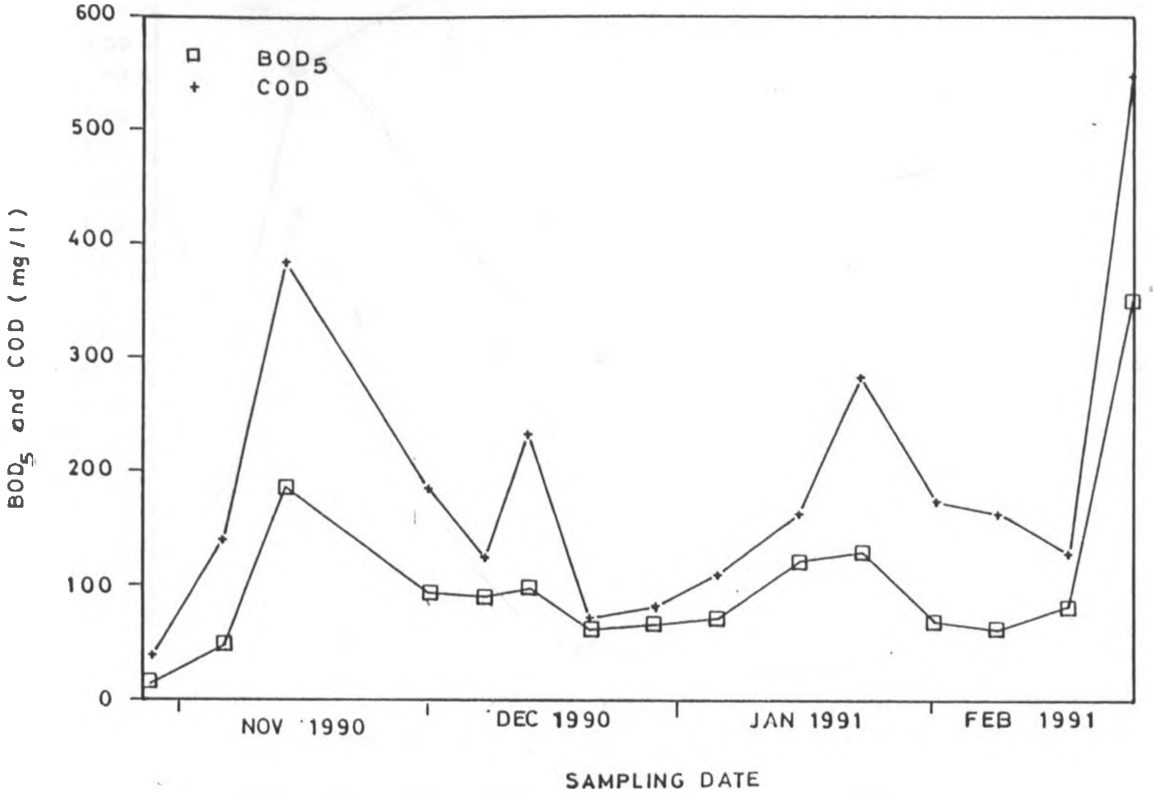


Fig 25 VARIATION IN BOD_5 AND COD FOR STATION 7

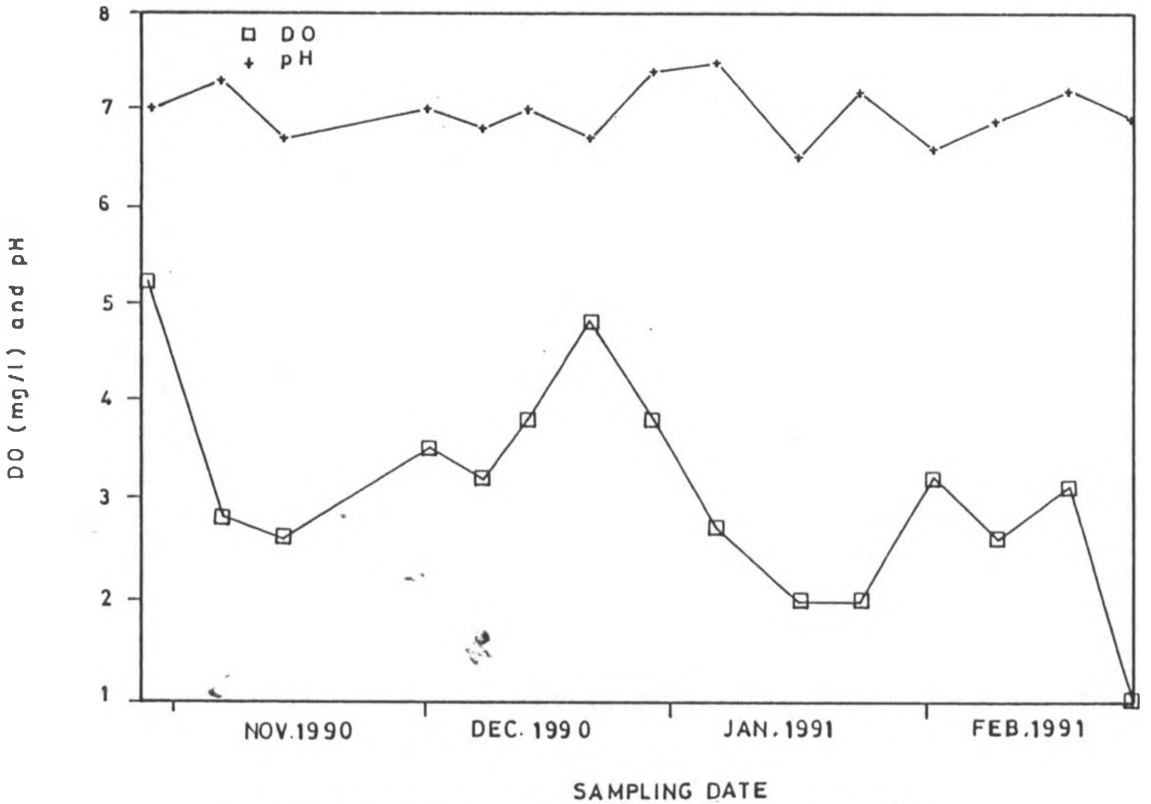


Fig 26 VARIATION IN DO AND pH FOR STATION 7

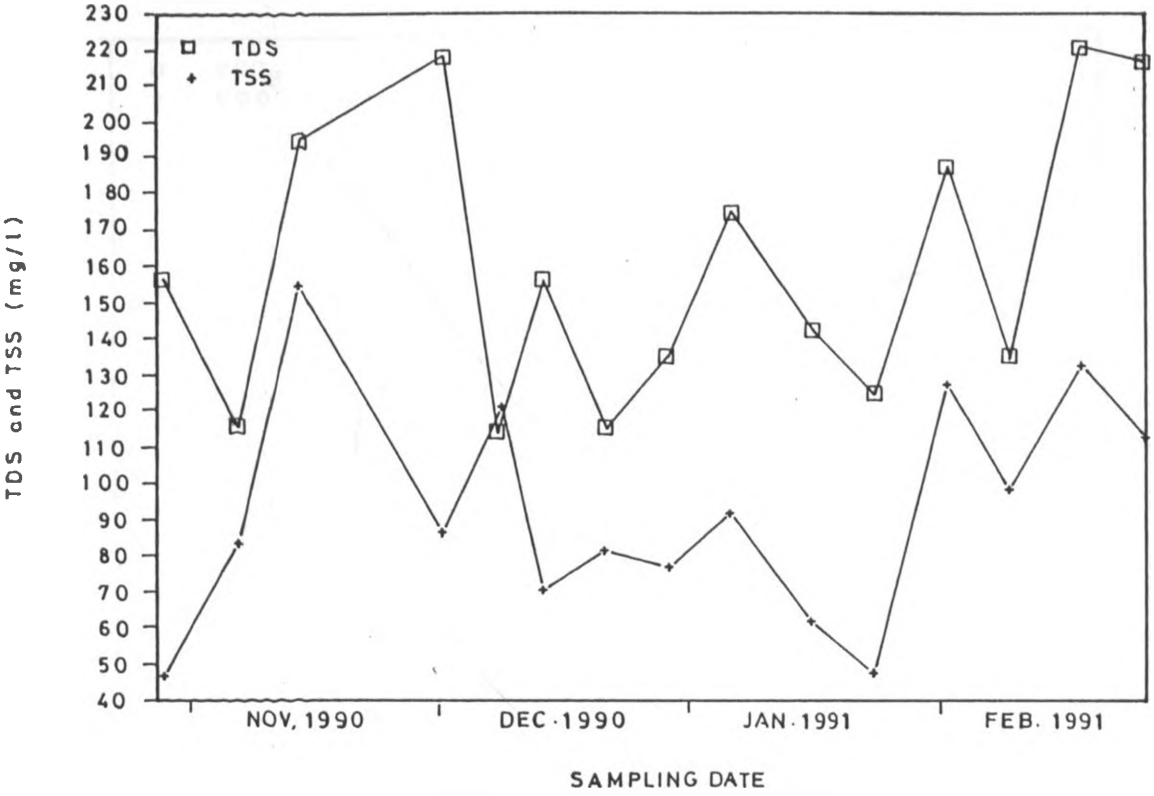


Fig 27 VARIATION IN TDS AND TSS FOR STATION 7

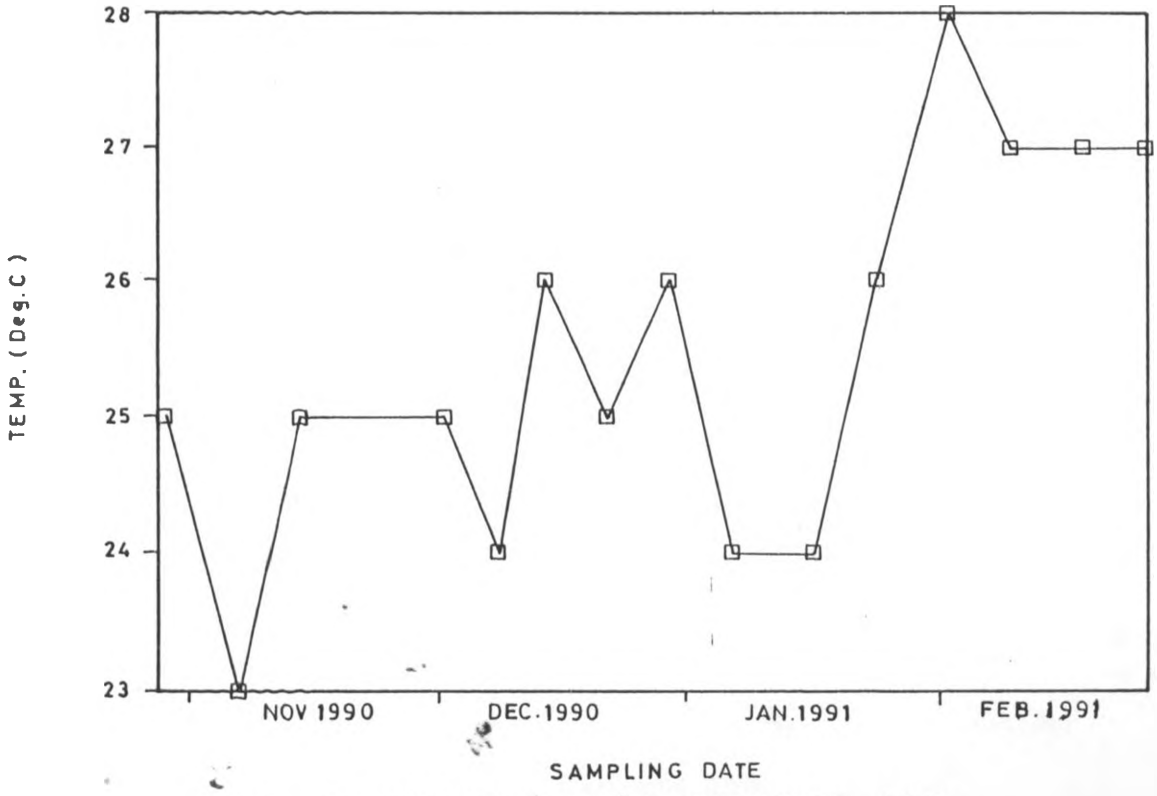


Fig. 28 VARIATION IN TEMPERATURE FOR STATION 7

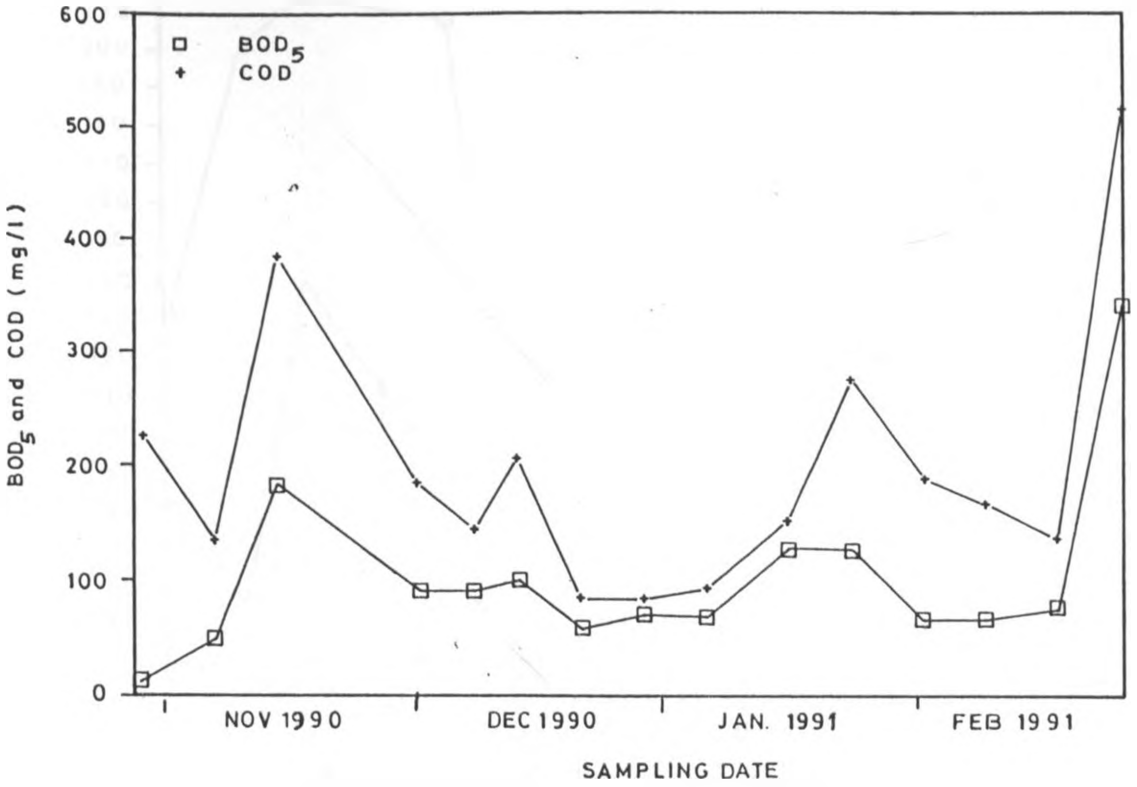


Fig. 29 VARIATION IN BOD_5 AND COD FOR STATION 8

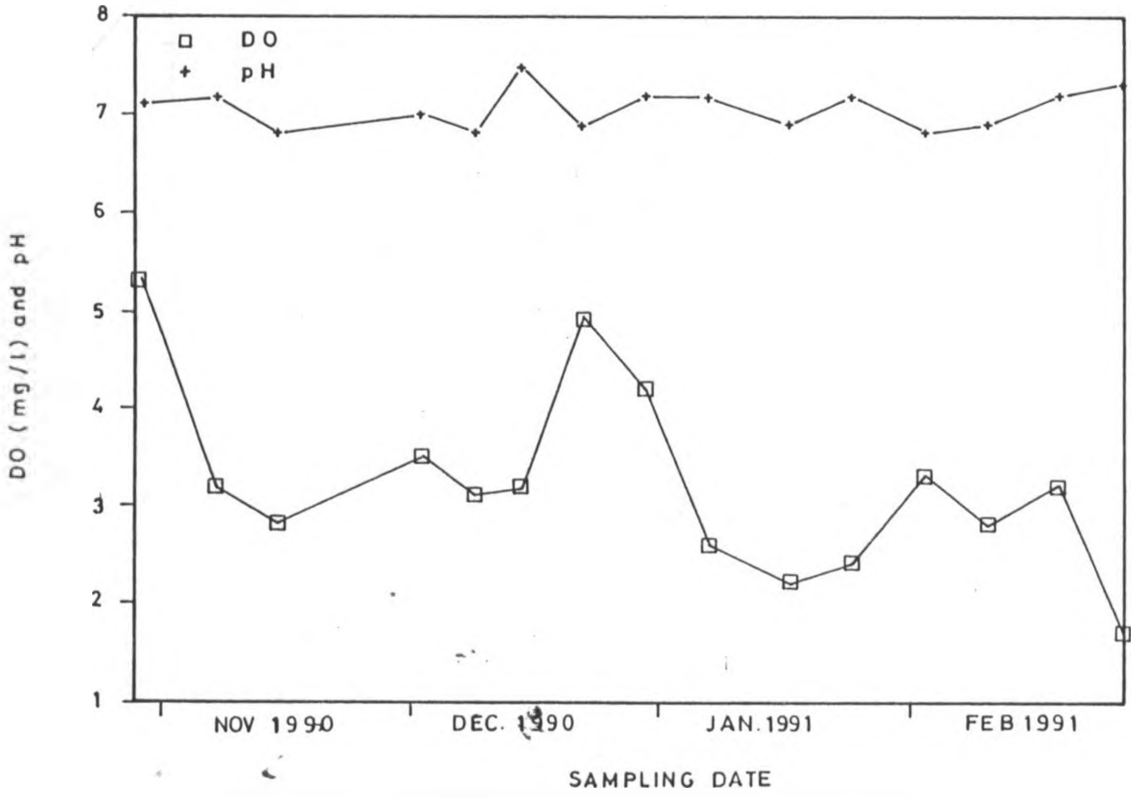


Fig. 30 VARIATION IN DO AND pH FOR STATION 8

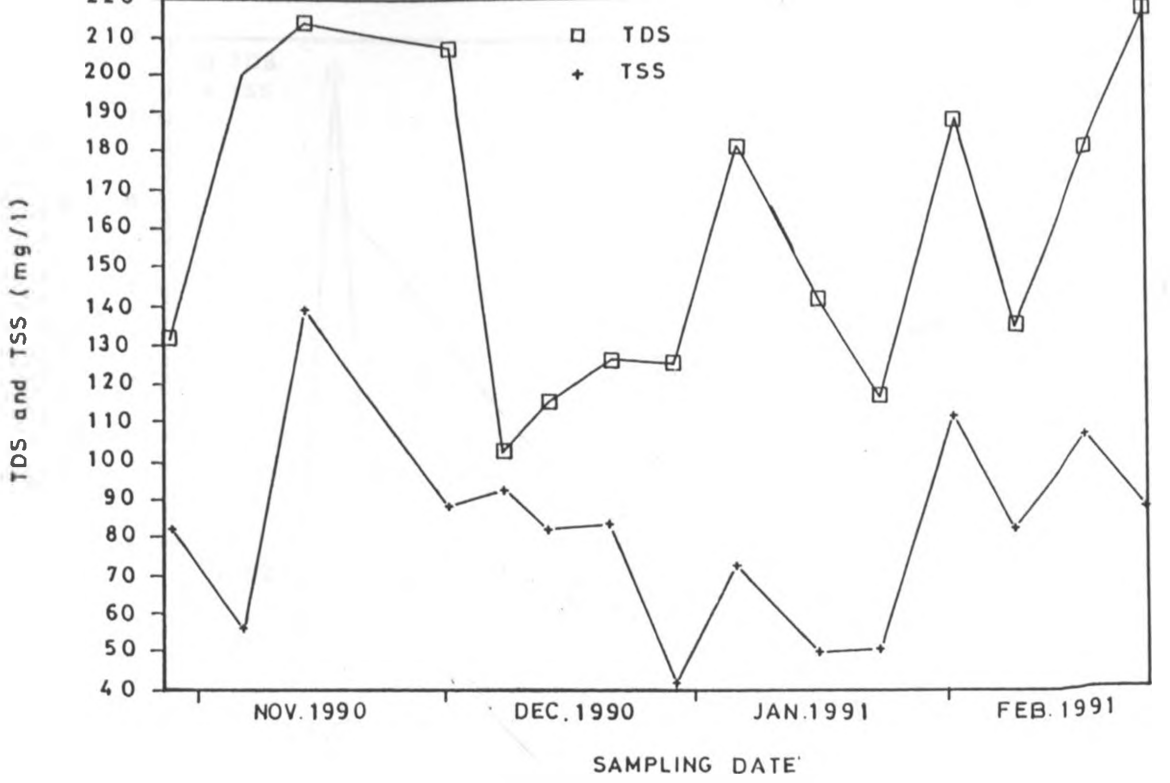


Fig. 31 VARIATION IN TDS AND TSS FOR STATION 8

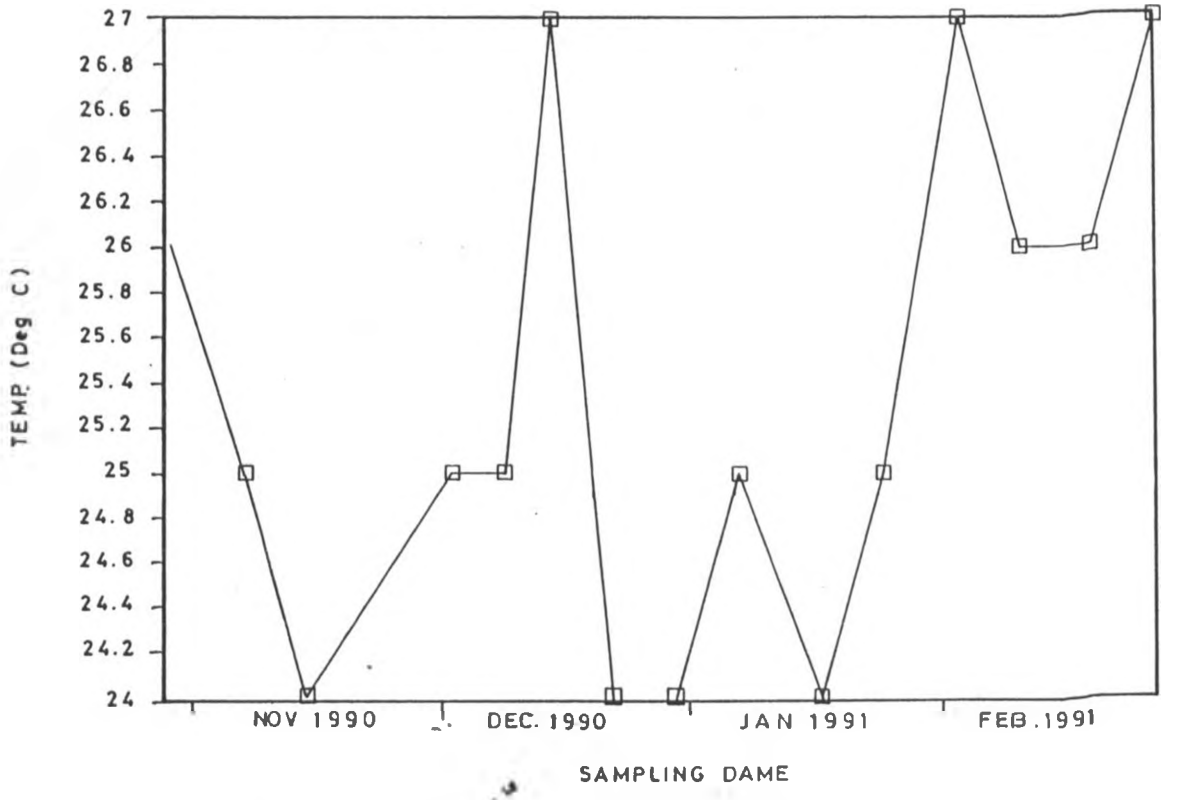


Fig. 32 VARIATION IN TEMPERATURE FOR STATION 8

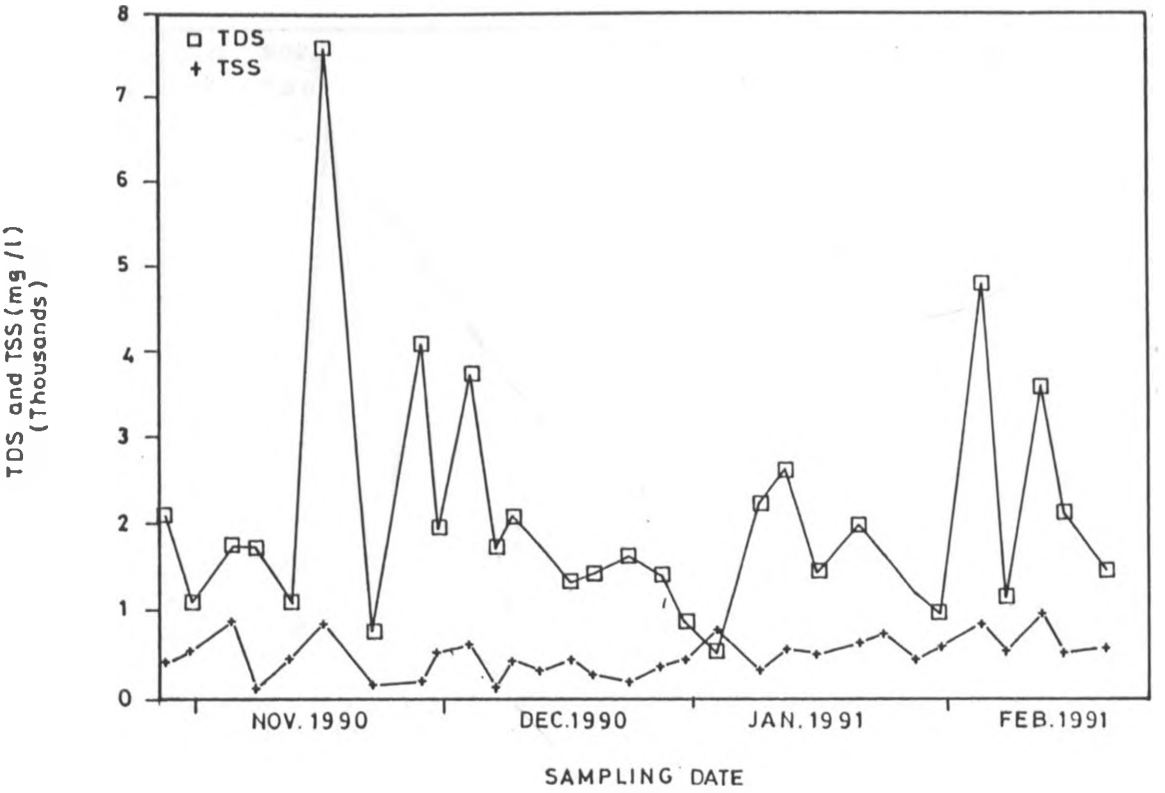


Fig. 33 VARIATION IN TDS AND TSS FOR STATION 9 WASTE FROM PARKING YARD AND SPOILT BEER

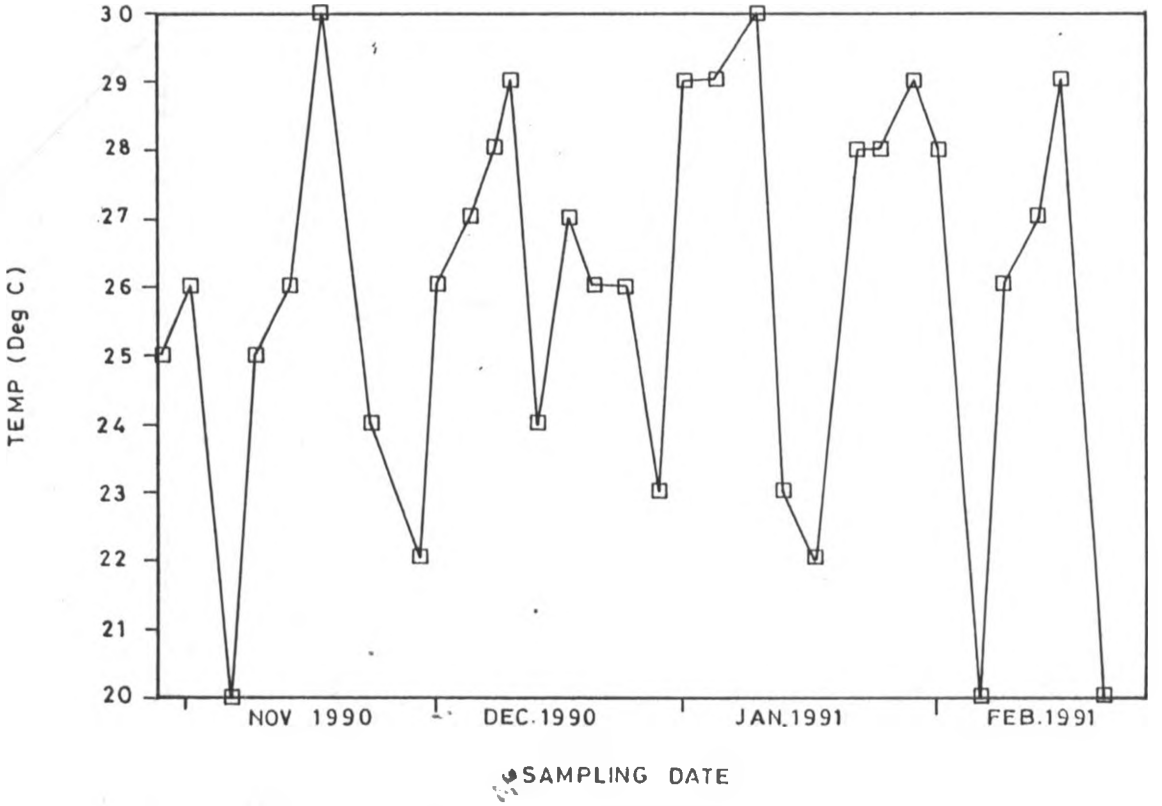


Fig. 34 VARIATION IN TEMPERATURE FOR STATION 9 WASTE FROM PARKING YARD AND SPOILT BEER

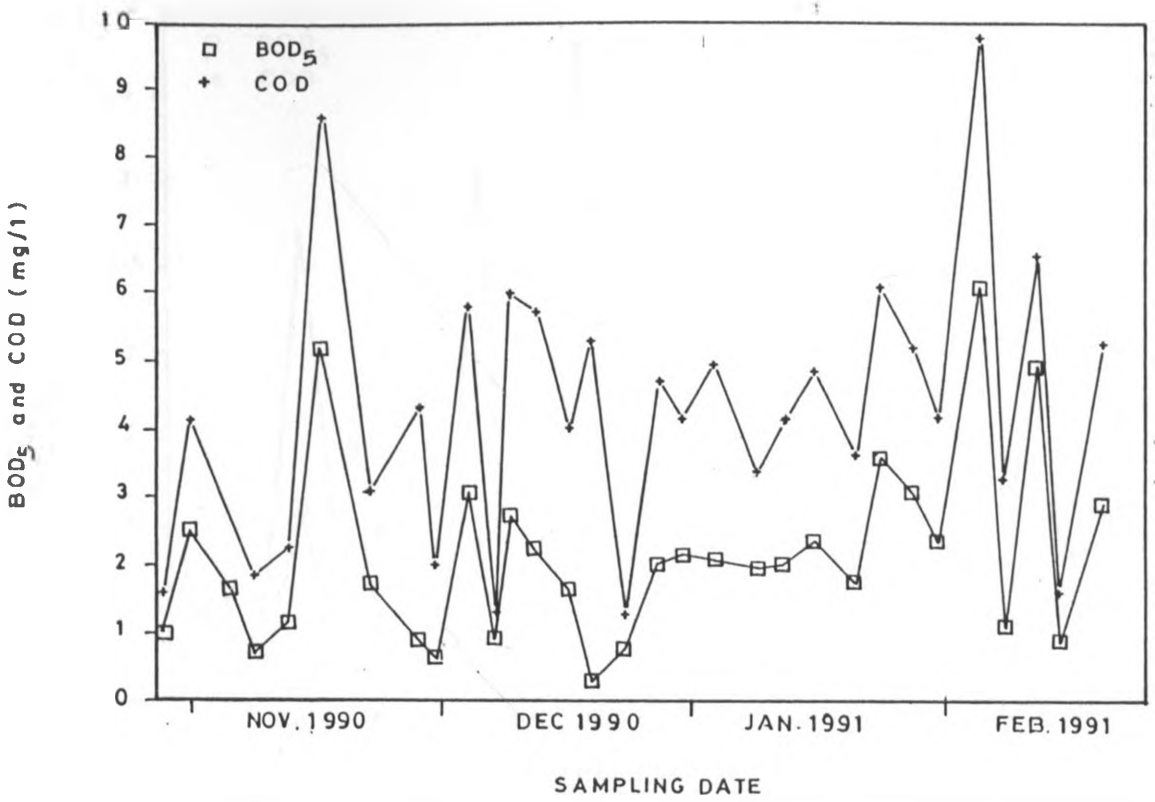


Fig. 35 VARIATION IN BOD_5 AND COD FOR STATION 9 WASTE FROM PARKING YARD AND SPOILT BEER

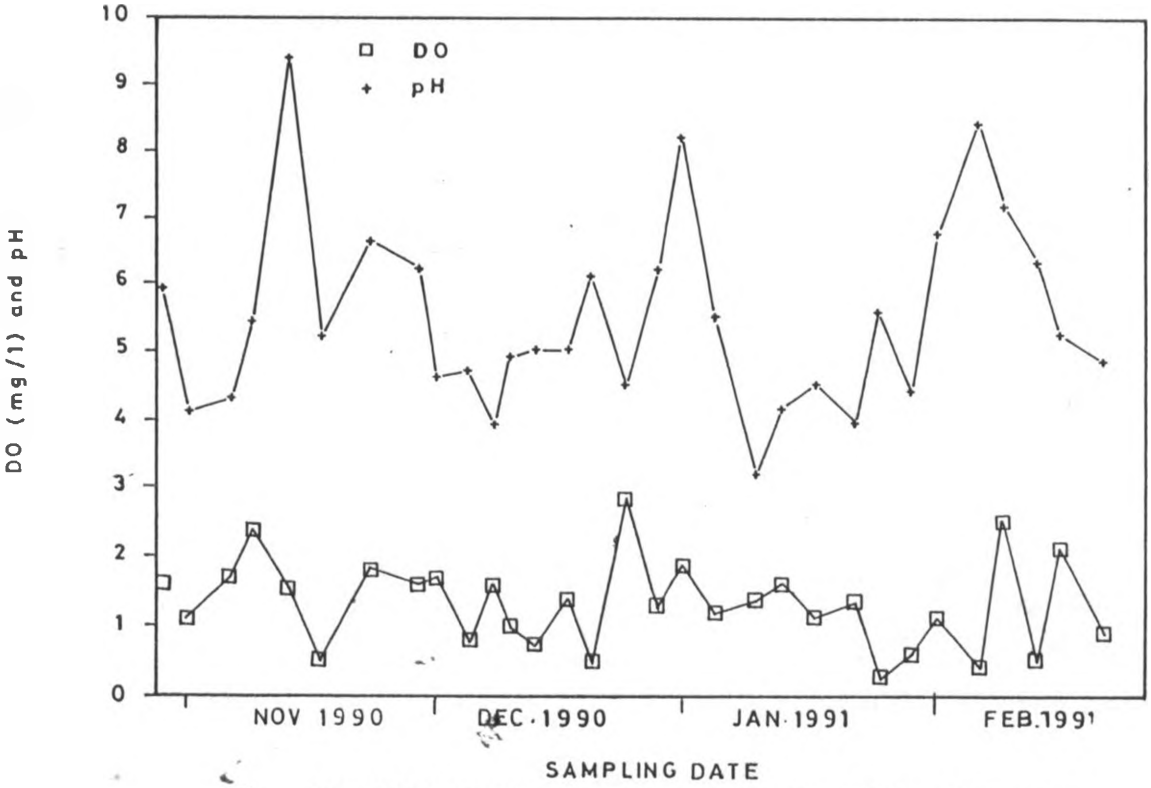


Fig. 36 VARIATION IN DO AND pH FOR STATION 9 WASTE FROM PARKING YARD AND SPOIT BEER

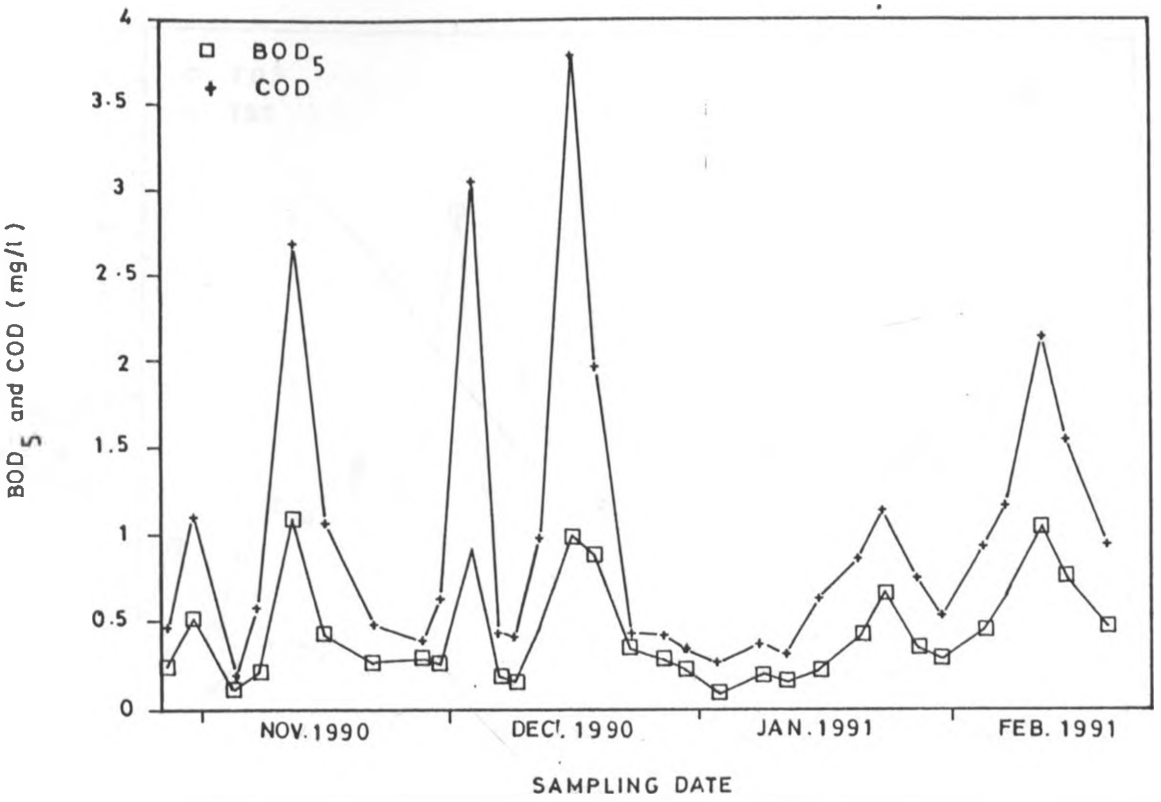


Fig. 37 VARIATION OF BOD_5 AND COD FOR STATION 10 WASTE FROM BOTTLING HALL (CHANNEL 1)

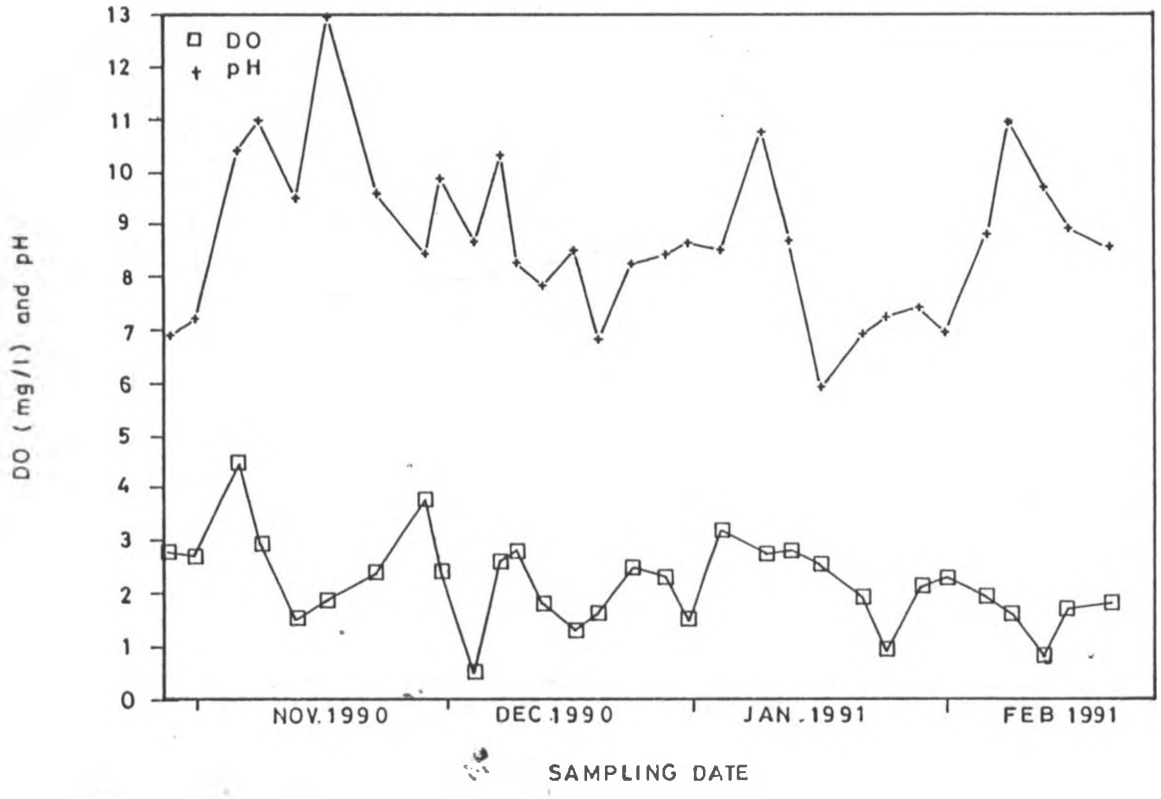


Fig. 38 VARIATION OF DO AND pH FOR STATION 10 WASTE FROM BOTTLING HALL (CHANNEL 1)

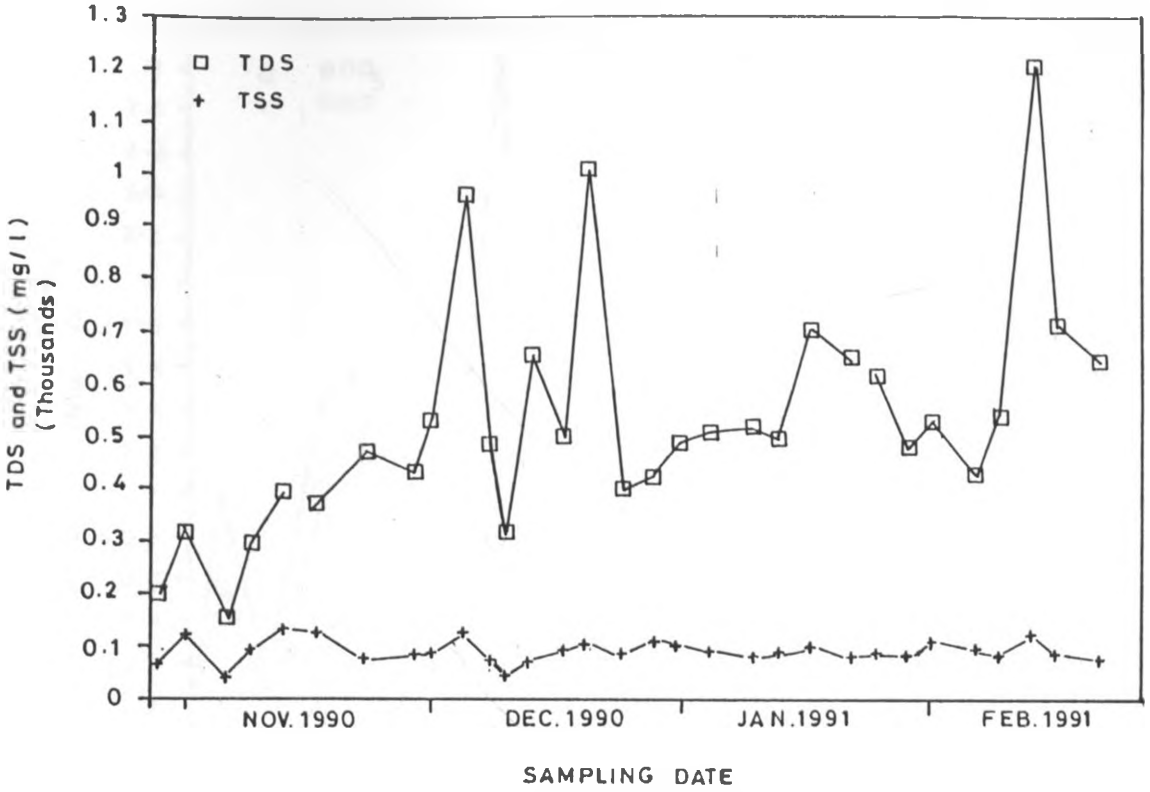


Fig. 39 VARIATION OF TDS AND TSS FOR STATION 10 WASTE FROM BOTTLING HALL (CHANNEL 1)

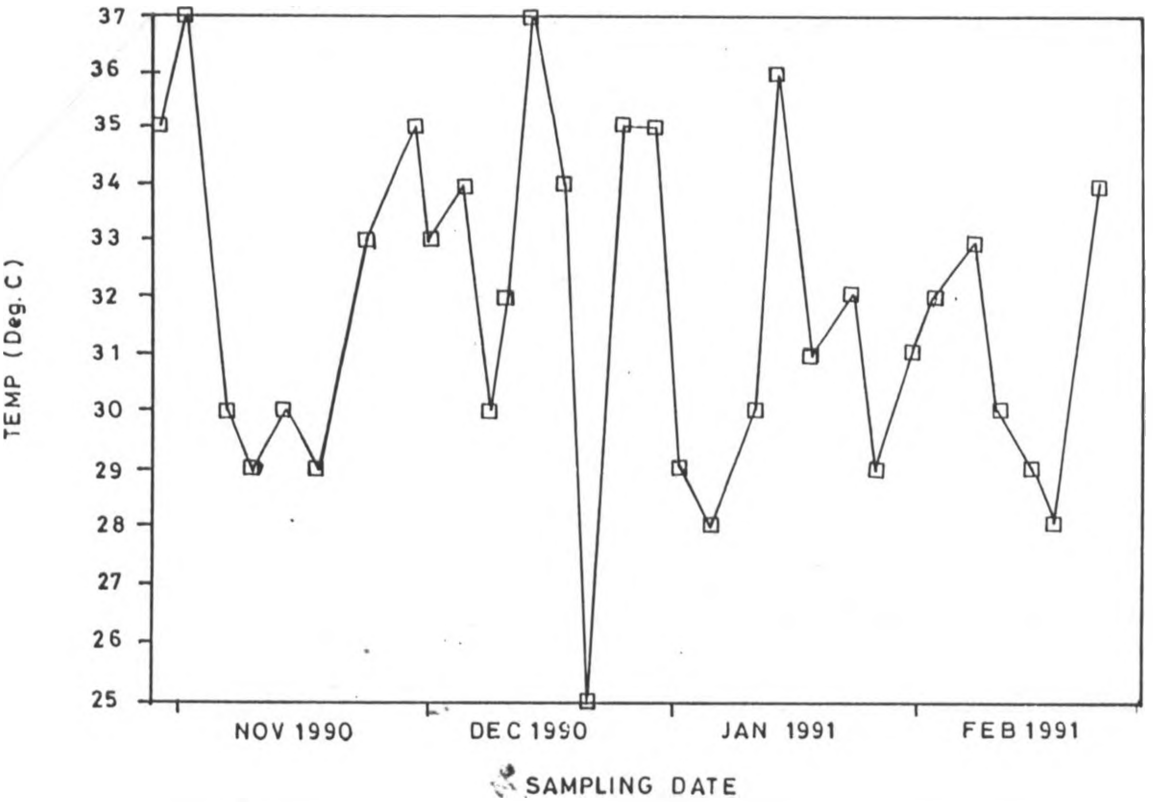


Fig. 40 VARIATION OF TEMPERATURE FOR STATION 10 WASTE FROM BOTTLING HALL (CHANNEL 1)

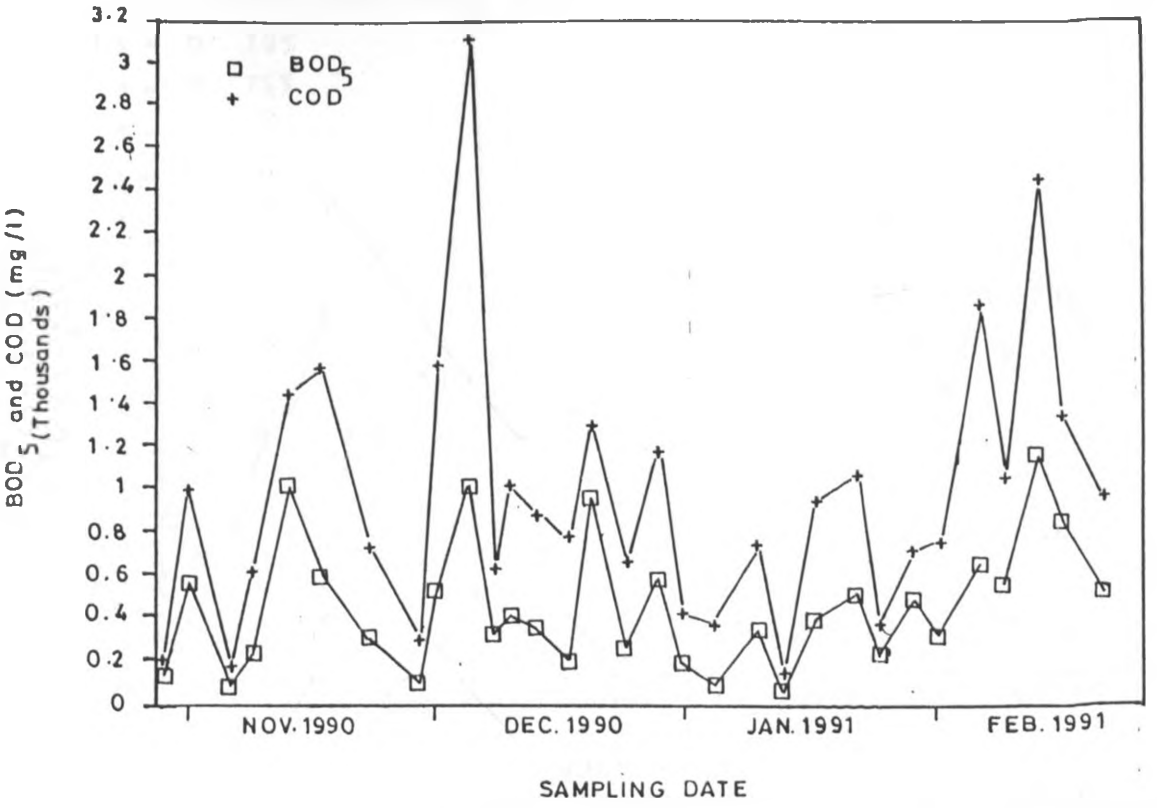


Fig. 41 VARIATION OF BOD_5 AND COD FOR STATION 11 WASTE FROM BOTTLING HALL (CHANNEL 2)

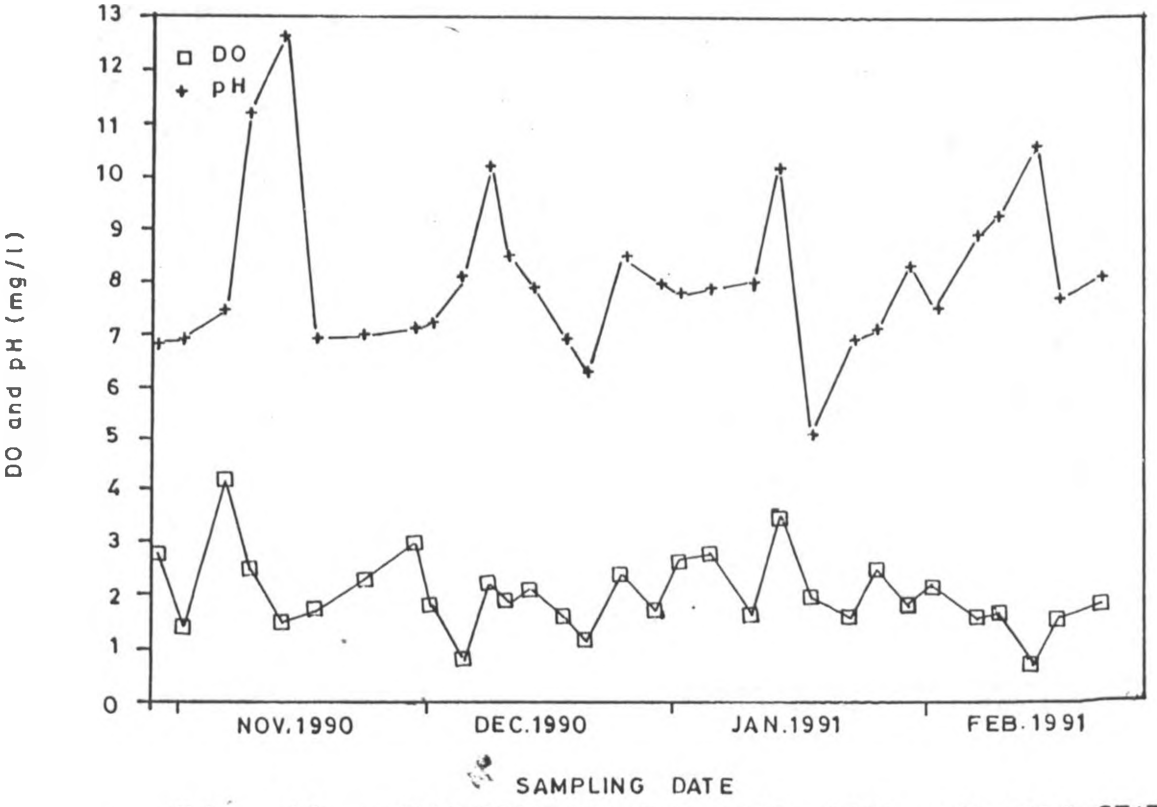


Fig. 42 VARIATION OF DO AND AND pH FOR STATION 11 WASTE FROM BOTTLING HALL (CHANNEL 2)

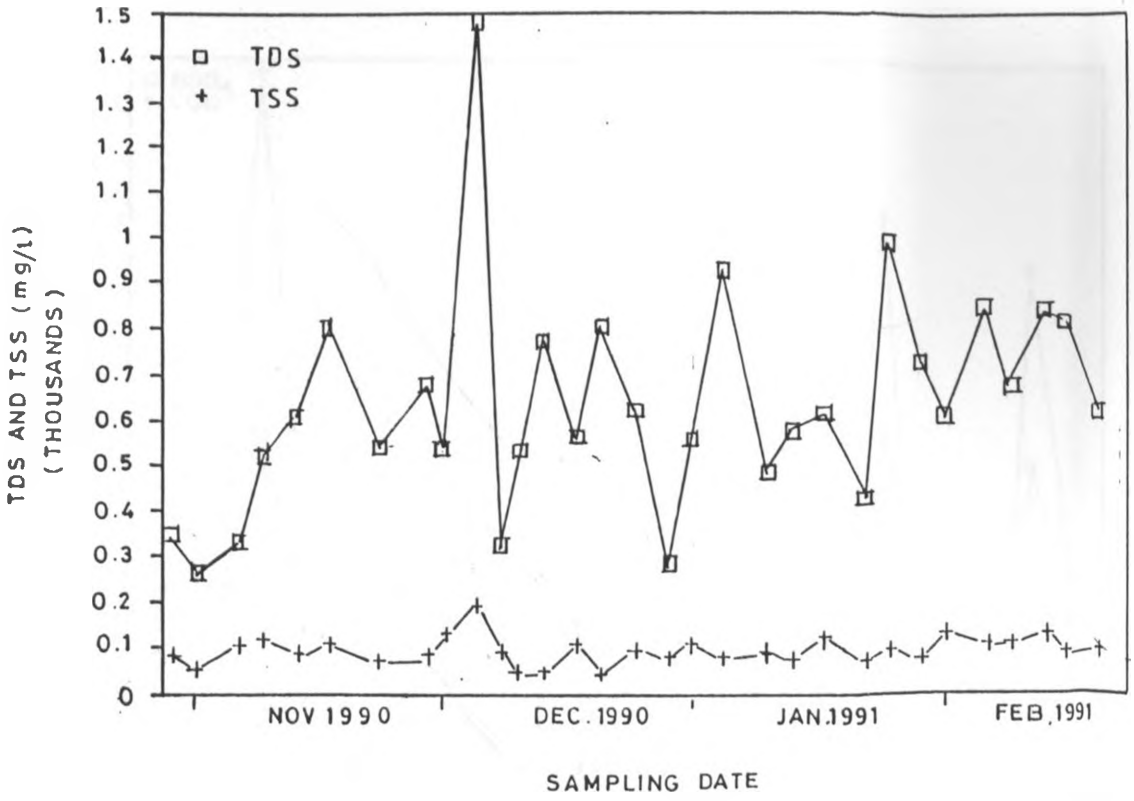


Fig 43 VARIATION OF TDS AND TSS FOR STATION 11 WASTE FROM BOTTLING HALL (CHANNEL 2)

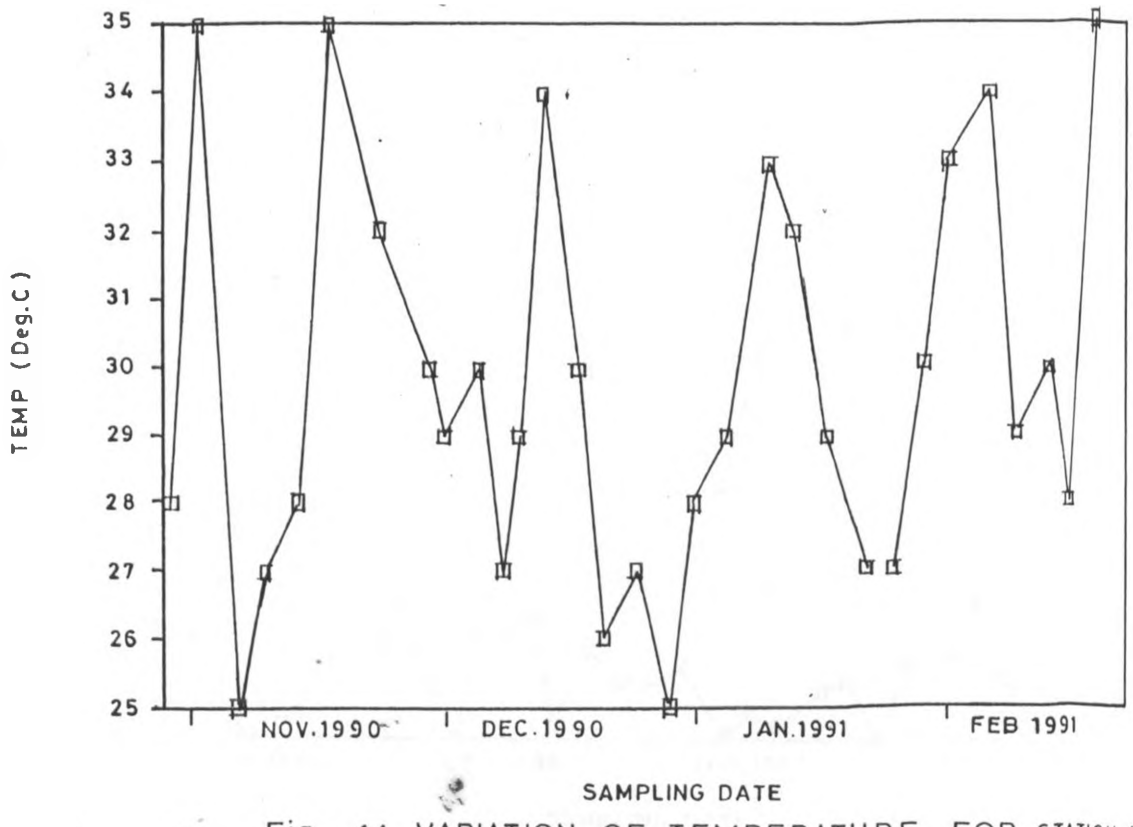


Fig 44 VARIATION OF TEMPERATURE FOR STATION 11 WASTE FROM BOTTLING HALL (CHANNEL 2)

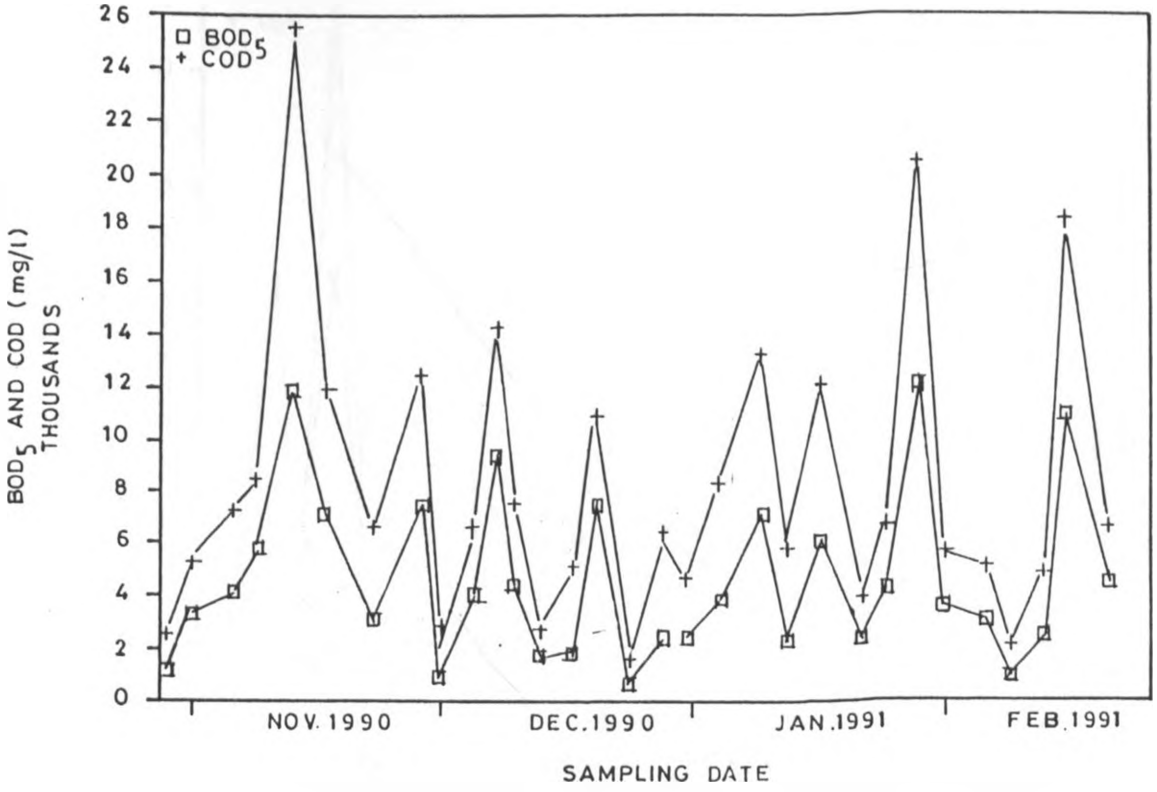


Fig 45 VARIATION OF BOD_5 AND COD FOR STATION 12 WASTE FROM BREWHOUSE AND BSP

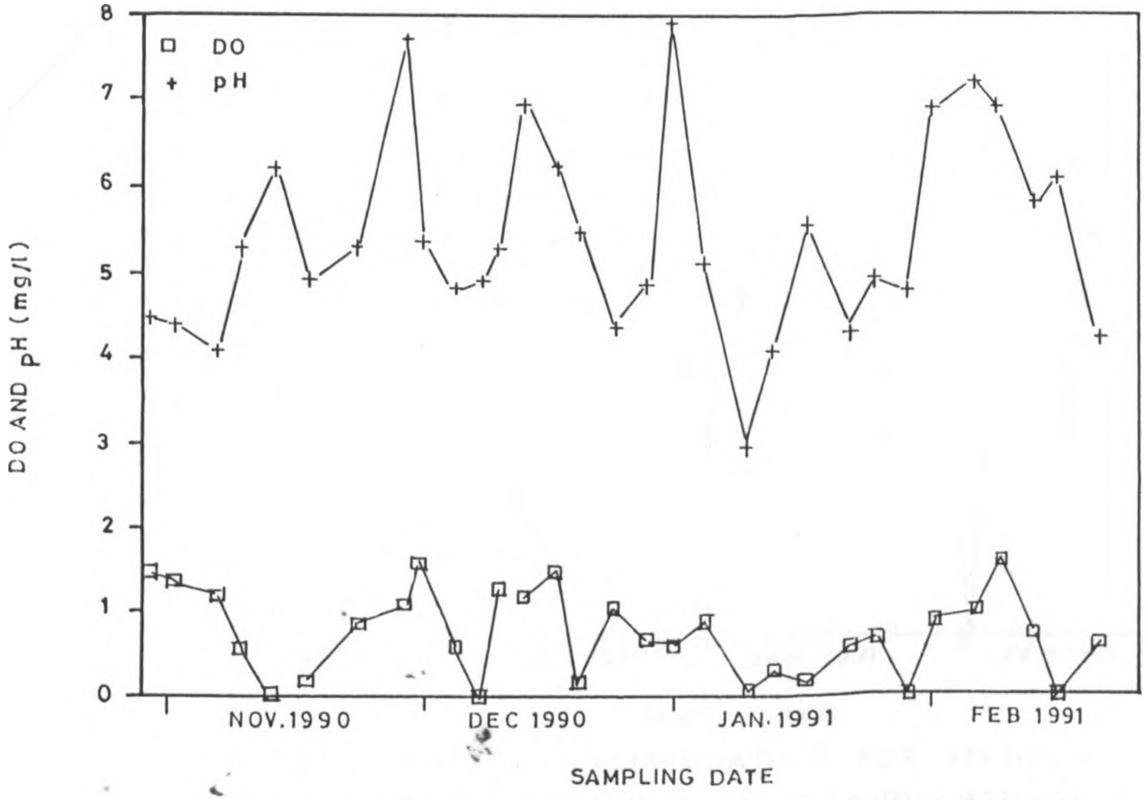


Fig. 46 VARIATION OF DO AND pH FOR STATION 12 WASTE FROM BREWHOUSE AND BSP

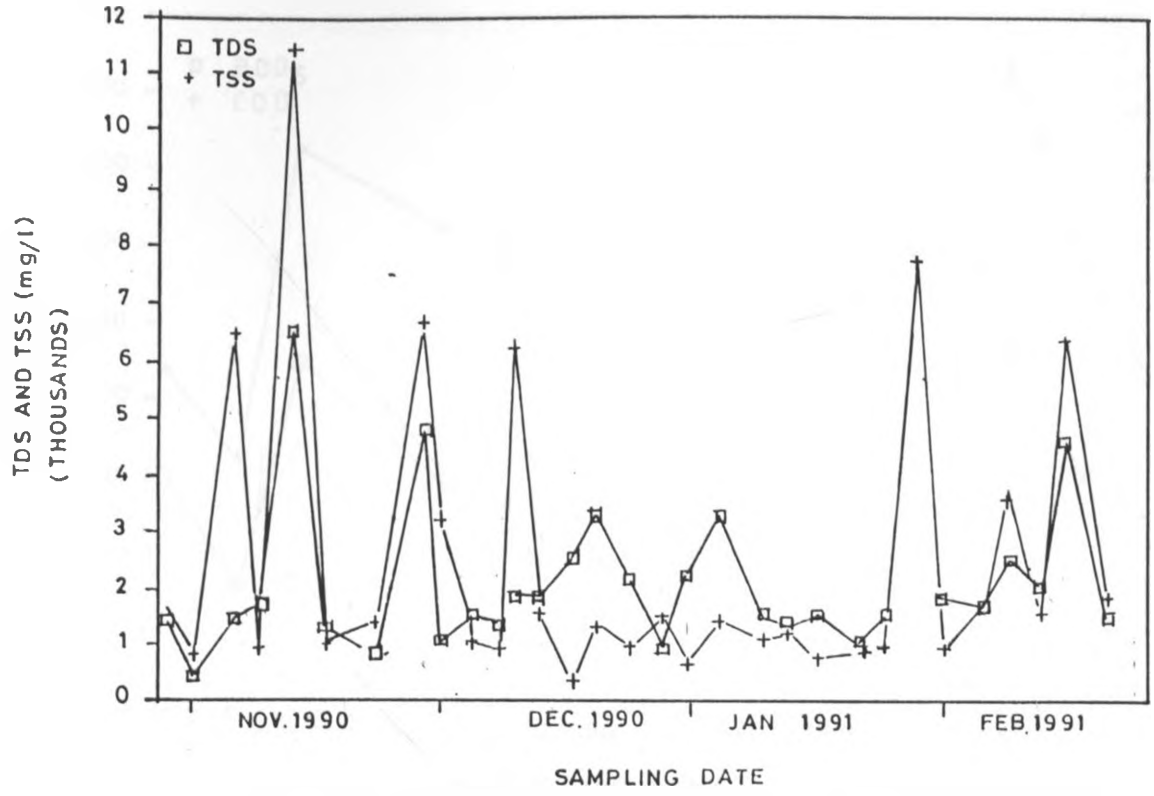


Fig 47 VARIATION OF TDS AND TSS FOR STATION 12 WASTE FROM BREWHOUSE AND BSP

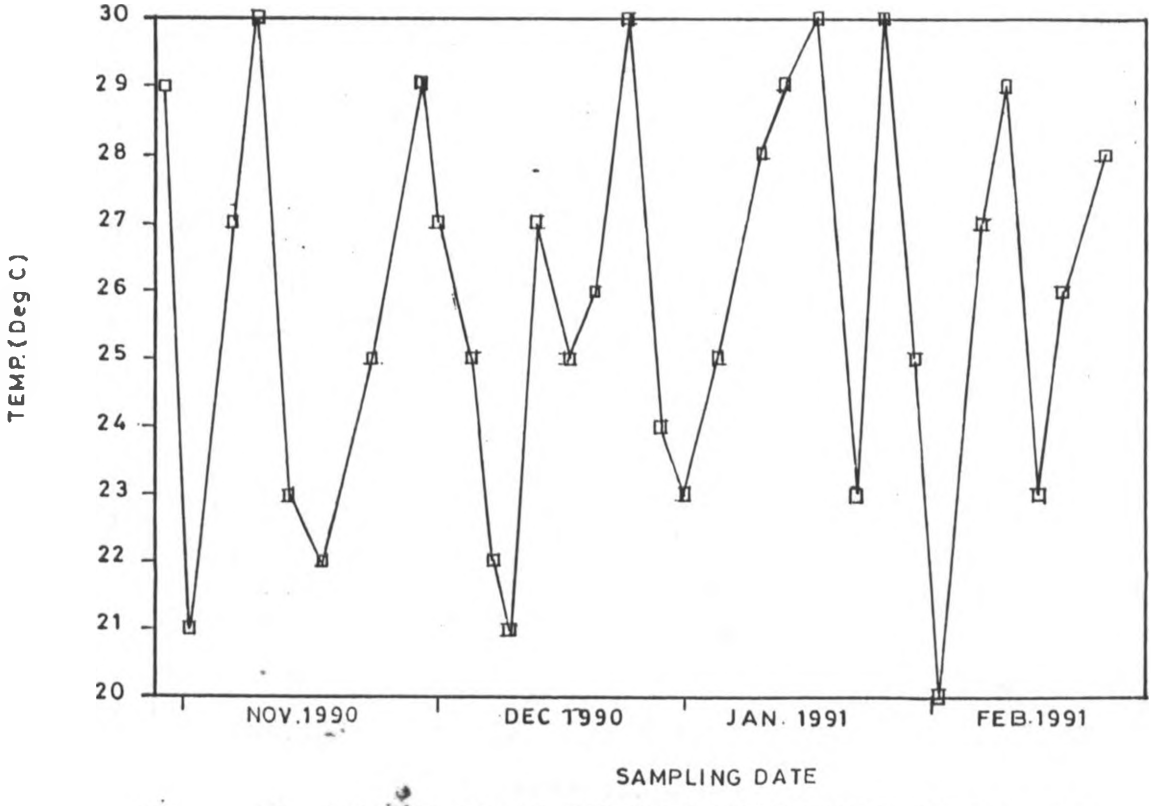


Fig. 48 VARIATION IN TEMPERATURE FOR STATION 12 WASTE FROM BREWHOUSE AND BSP

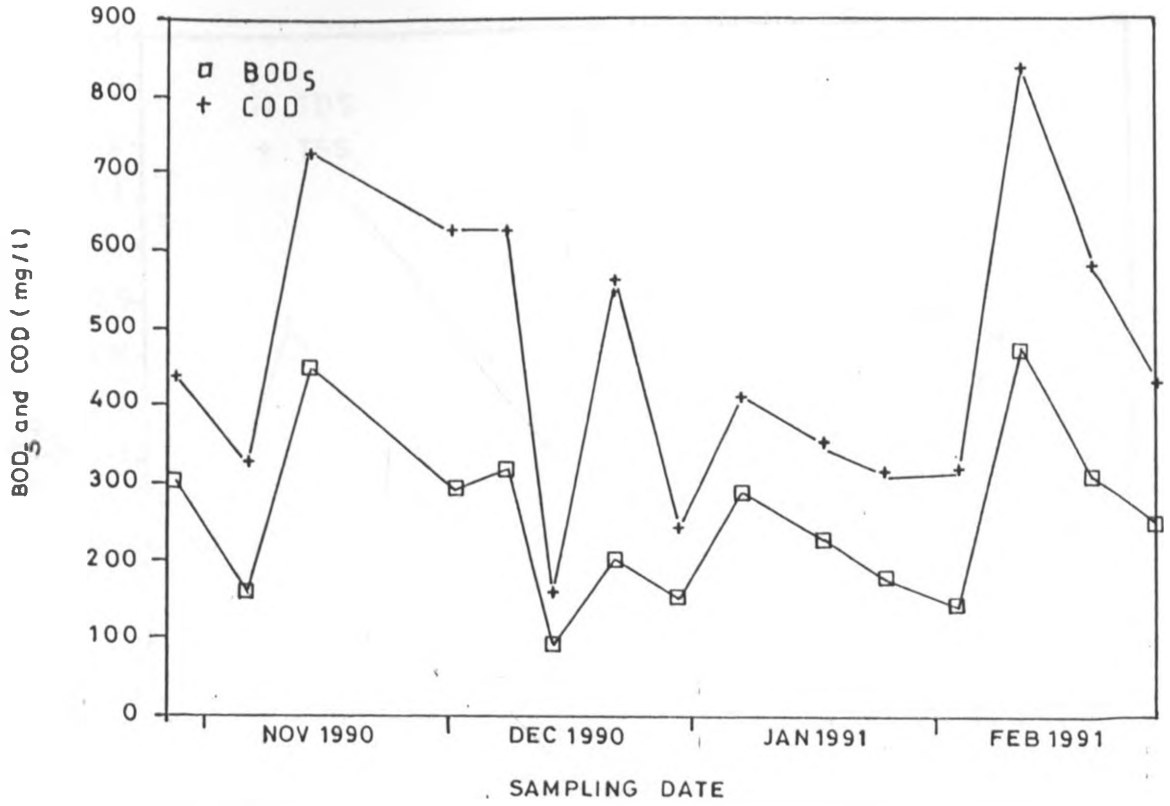


Fig. 49 VARIATION IN BOD_5 AND COD FOR STATION 13 SEWAGE FROM TUSKER VILLAGE & OFFICE

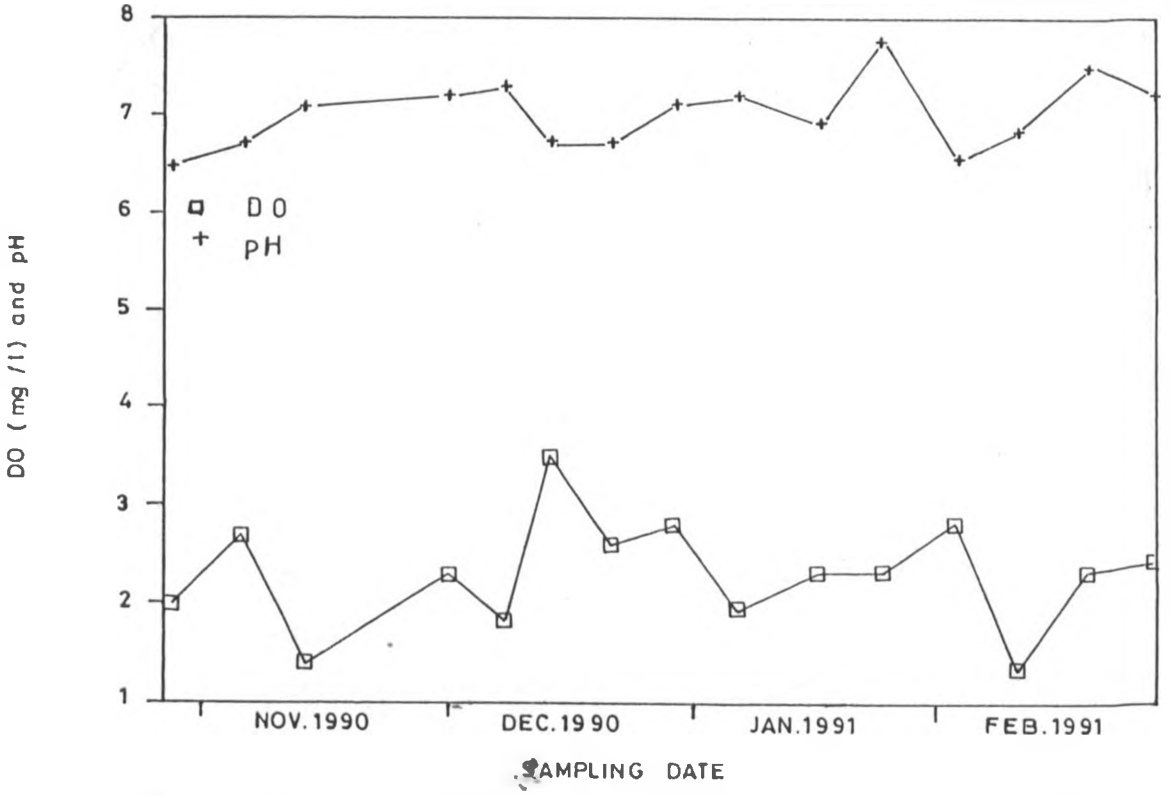


Fig. 50 VARIATION OF DO AND pH FOR STATION 13 WASTE FROM TUSKER VILLAGE AND OFFICE

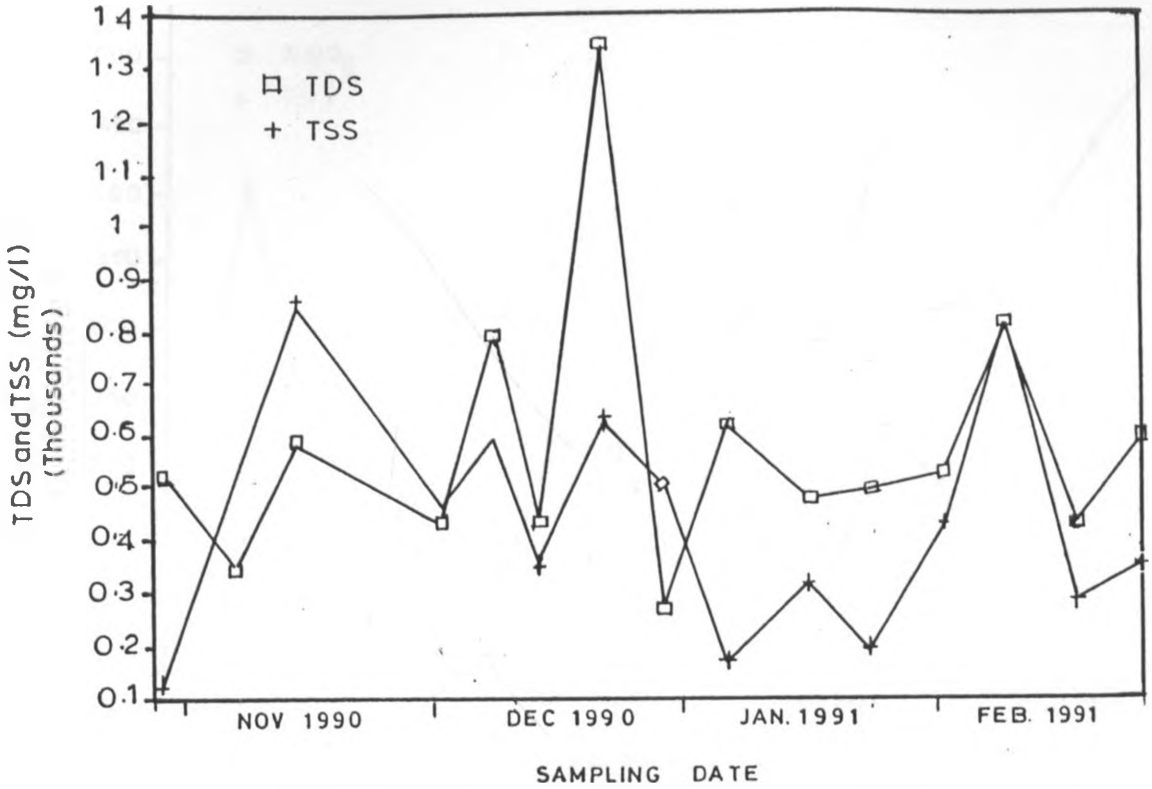


Fig 51 VARIATION IN TDS AND TSS WASTE FROM TUSKER VILLAGE AND OFFICES - STATION 13

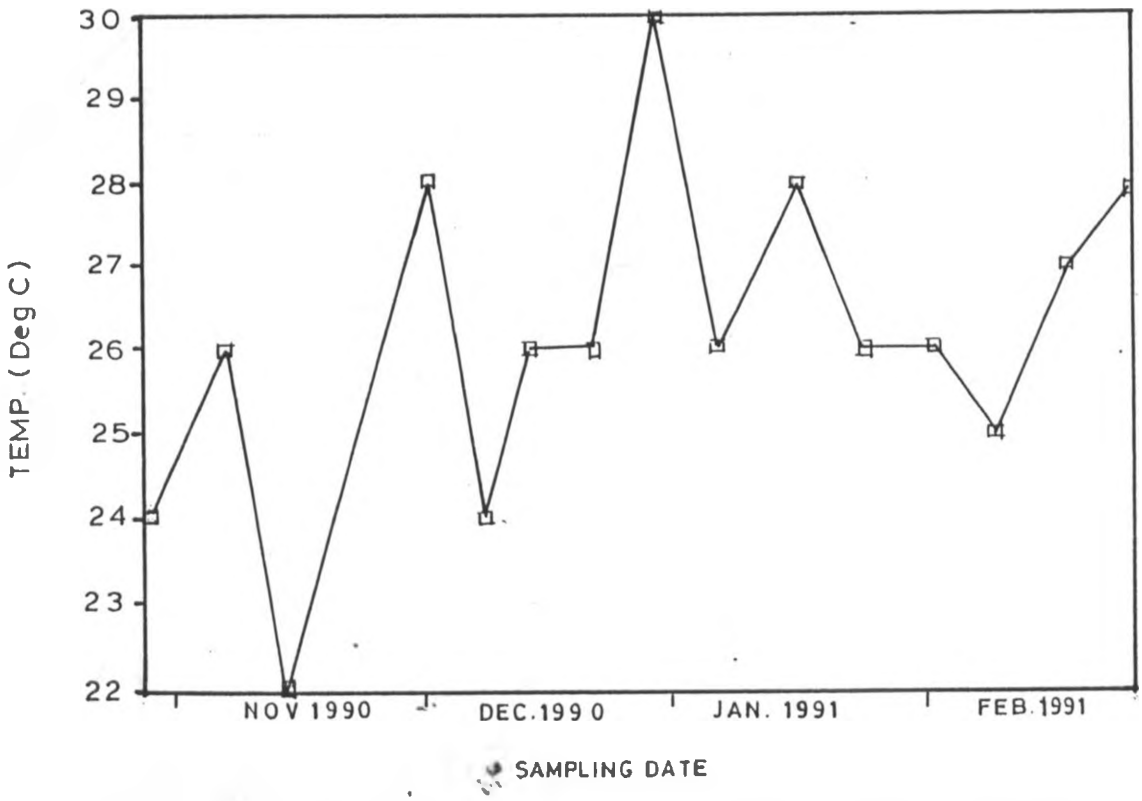


Fig. 52 VARIATION IN TEMPERATURE WASTE FROM TUSKER VILLAGE AND OFFICES - STATION 13

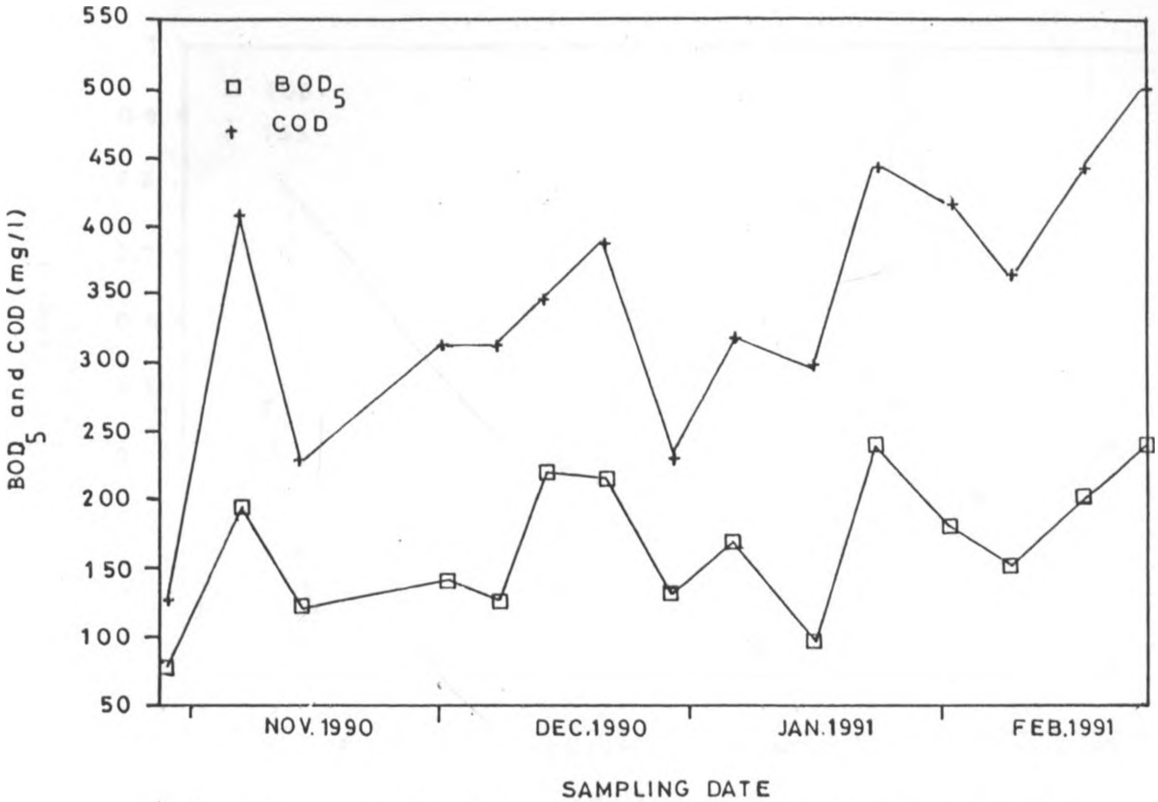


Fig. 53 VARIATION IN BOD_5 AND COD . SEWAGE FROM NGUMBA AND SAFARI PARK AREA - STATION 14

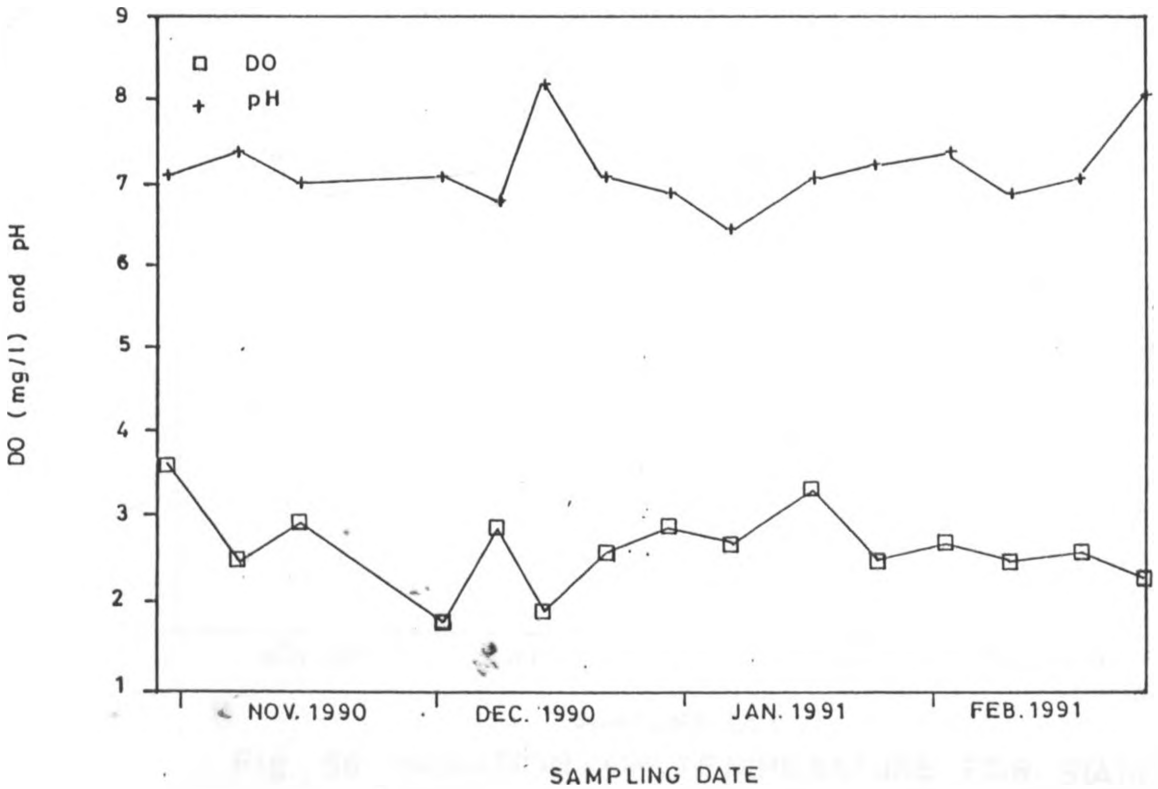


Fig. 54 VARIATION FROM DO AND pH FOR WASTE FROM NGUMBA AND SAFARI PARK AREA - STATION 14

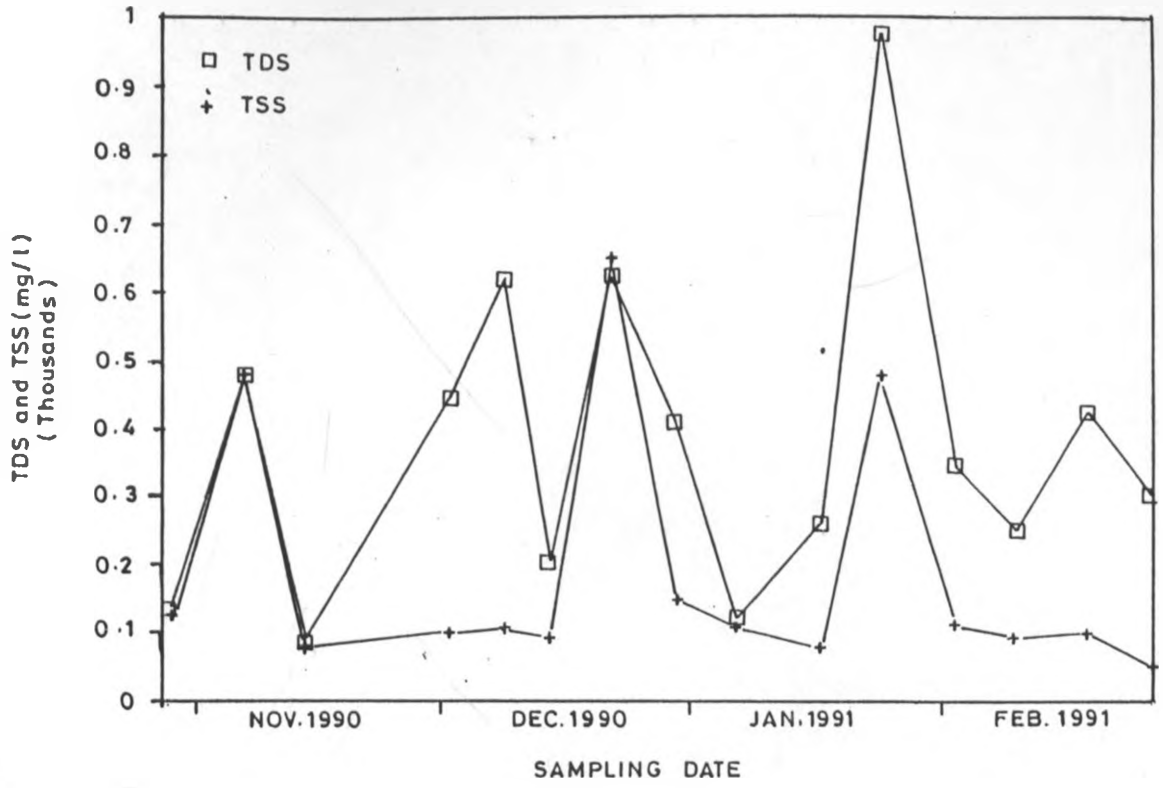


Fig. 55 VARIATION IN TDS AND TSS FOR STATION 14
(SEWAGE FROM NGUMBA AND SAFARI PARK AREA)

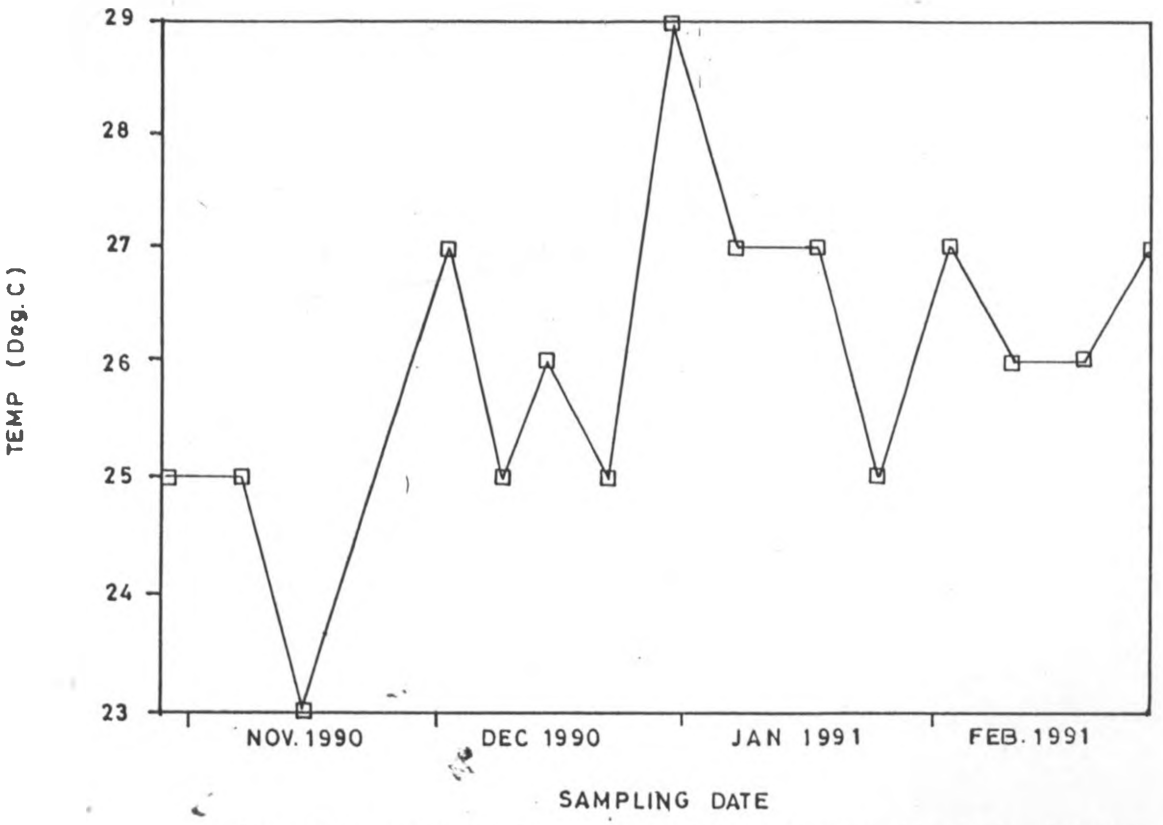


Fig. 56 VARIATION OF TEMPERATURE FOR STATION 14
(WASTE FROM NGUMBA AND SAFARI PARK AREA)