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EFFECT OF WASTE DISPOSALS ON QUALITY OF WATER OF RIVER KALI (UTTAR PRADESH)

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PREFACE

With the rapid increase in population and growth of industrialisation in the country, pollution of natural water by municipal and industrial wastes has increased tremendously. The pollution is objectionable and damaging for varied reasons. Of primary importance are the possible hazards to the public health. Of a lesser consequence, but still very real, is the aesthetic damage to the attributes of streams and destruction of the economic values of clean natural waters. The pollution of rivers and streams by industrial wastes and domestic sewage has increased tremendously and producing the most unsanitary conditions in the environment.

The role of water quality engineer and scientist is to analyse water quality problems by dividing the problems into its principal components, viz., inputs, the reaction and physical transport and the output.

Considering these aspects in view, it has been planned to study the effect of waste disposals on the quality of water of river Kali (U.P.). The present investigations would be a step towards understanding the nature of pollutants and their effects on the quality of water of the river. The report also describes upstream/downstream approach for measuring the changes in the concentration and/or load to the river.

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ABSTRACT

A detailed survey of the river Kali was conducted to understand the nature of pollutants and their effect on the quality of water of the river. From the study conducted, it was revealed that the water in the river Kali is subjected to varying degree of pollution, caused by numerous untreated outfalls of municipal and industrial effluents. The main sources which create pollution in river include, municipal waste of Muzaffarnagar city, industrial waste from variety of industries (such as steel, rubber, ceramic, chemical, plastic, dairy, pulp and paper and loundaries) and Mansurpur sugar mill and distillery waste. The wastes from variety of industries transfer their wastes through Muzaffarnagar main drain into the river.

The report also gave an account of magnitude of pollution caused by the discharges of municipal and industrial wastes. These wastes contain high BOD, COD and total solids. The detailed survey of the river indicate that the river is grossly polluted due to the numerous outfalls of untreated municipal and industrial wastes, thus bringing about a considerable change in the river water quality. Such a change is of significance and has more consequences for rural population on the banks of river downstream. The important characteristics associated with the pollution of the river is the depletion of oxygen over a stretch of about 25 kms.

The mass balance conducted for some water quality constituents for river Kali shows that changes found in load along the river may be mainly due to the contribution of non-point sources of pollution. The difference may also be attributed due to some point sources of pollution which could not be identified in the course of investigations.

1.0 INTRODUCTION

1.1 General

The water of rivers and fresh water lakes plays an important role in over all development programmes of the country. They also serves as a source of water supply for domestic and industrial purposes and also for agriculture, fisheries and power development. The same water resources are also utilised for the disposal of industrial wastes and sewage, leading to water pollution.

The pollution problem arises principally from the discharge of the residues of human and natural activities that result, in some way, in an interference of a desirable use of water. The pollution of rivers and streams by industrial wastes and domestic sewage has increased tremendously and producing the most unsanitary conditions in the environment.

The principal sources of pollution can be divided into two broad categories: (a) discrete or point sources and (b) diffuse or non-point sources. The point sources are those inputs that are considered to have a well-defined point of discharge which, under most circumstances, is usually continuous. The two principal point source groupings are: (a) municipal point sources that result in discharges of treated and partially treated sewage with associated bacteria and organic matter, biochemical oxygen demand, nutrients and toxic substances, and (b) industrial discharges which also result in the discharge of nutrients, BOD and hazardous substances.

The principal non-point sources are: (a) agriculture, (b) atmospheric, (c) urban runoff and (d) groundwater. In each case, the distinguishing feature of the nonpoint source is that the origin of the discharge is diffuse. That is, it is not possible to relate the discharge to a specific well-defined location. Furthermore, the source may enter the given river or lake via overland runoff as in the case of agriculture or through the surface of the land and water as an atmospheric input.

One of the most important sources of water pollution is due to human activities. Even today, open defaecation in the fields and along the drains and water resources is common in India. This creates lots of challengeable health implications. Even in class I cities of the country, only 26 % of the population is covered by sanitation. One can easily imagine the height of inefficiency and the extent of its hazardous effects on human health.

Industries are also of great concern and industrialisation contributing to water pollution has reached an alarming situation. Less than 5 % of the industries have provided adequate measures for the treatment of effluents and even most of them have neglected this totally. The industrial wastes generally contains:

a) Oil : forming a thin, widely dispersed film on the surface, it reduces the uptake of oxygen by the water.

b) Detergents : they reduces oxygen absorption capacity of fresh water.

c) Suspended particles : these produce similar effects in water to those of soot in atmosphere.

d) Poisonous chemicals (such as sulphides and sulphites) : acting as reducing substances, these lower down the oxygen concentration in the water.

Fertilizers and chemicals are also listed among important pollutants, however, the input of these chemicals per hectare cultivated land is still low.

Almost all major cities of the country are facing pollution problems. Enormous amount of sewage and industrial effluents are being discharged into the nearby water course without any treatment. The Kallu river near Kalyan affords highly acidic water (pH 1.5) due to these kinds of discharges. Hooghly river near Calcutta, Ganges from Kanpur to Allahabad, Damodar near Asansol and Durgapur, Jamuna near Delhi and Agra, Gomti near Lucknow, Hindon near Saharanpur flow under similar state.

Surface water often have taste and odour problems particularly in regions of dense population. These are generally caused by industrial and domestic pollution, algae, aquatic vegetation, decaying vegetation and runoff from agricultural regions. Pollutional effects due to the discharges of municipal and industrial wastes into the rivers have been studied by various workers.

In western districts of Uttar Pradesh (U.P.), mainly Saharanpur, Muzaffarnagar, Meerut and Bulandshahar, large number of water resources are present which are used for irrigation, fish catch, to procure fish seed and fingerlings. The same water resources are also utilized for the disposal of industrial wastes of more than 20 different industries (Verma et al. 1974). The main water resources of this region are river Hindon, Kalinadi, Krishna, Ganga, Jamuna with their respective tributaries and four canals. Verma et al. (1974) studied the characteristics and disposal problems of various industrial effluents with reference to Indian standards. They also made a detailed study on the pollution of river Hindon in relation to fish and fisheries (Verma et al., 1980) and stream Khala by the sugar factory effluent near Laksar in district Saharanpur (Verma and Shukla, 1969). Arora et al. (1973 and 1974) made a survey of sugar mill effluent treatment and disposal in some typical sugar mills of Uttar Pradesh, which is the largest sugar cane producing state in India, and reported that effluents are rich in suspended solids, BOD and grease and hence have a great pollution potential. Mohanrao (1972) studied the characteristics of dairy waste with reference to Indian standards. Verma and Dalela (1975) studied the pollution of Kalinadi by industrial wastes near Mansurpur.

In western Uttar Pradesh rapid industrial and agricultural growth has taken place during last two-three decades. This is likely to become manifold in near future particularly in areas like Muzaffarnagar where necessary industrial nucleus already exists. A variety of industries have already been set up in this area such as paper and pulp, sugar, chemicals, rubber, plastic, food-processing, small scale steel industries and cottage industries etc. Most of these industries are discharging their wastes and effluents into river Kali without considering its consequences. In addition to this, the municipal waste of Muzaffarnagar city and effluants from Mansurpur sugar mill and distillery are also being discharged into the river. On account of these outfalls of municipal and industrial wastes into the river, the water is subjected to varying degree of pollution.

The present investigation would be a step towards understanding the nature of pollutants and their effects on the quality of water of the river.

For understanding the relationship between the water quality found and the sources of natural and man-made pollution, the drawing up of mass balance for certain water constituents is of great help. This is done by determining the load of selected substances, i.e. the weight of the substance transported through a cross-section of the river bed per second. The dimension of a load is mg/liter (concentration) times liter/s (flow) = mg/s.

When two or more rivers come together at one point, the sum of the loads carried by the streams above the confluence must be equal to the load of the river downstream of this point. This enables us to check the measurements done. Changes found in a load along a river can point to dilution or point- or non-point sources of pollution not yet identified.

1.2 Scope of the Study

Characterization of wastes is essential for an effective and economical waste management programme. It helps in appropriate utilization of natural sinks - land, water bodies, atmosphere, choice of treatment methods, deciding the extent of treatment and assessing beneficial uses of wastes. Most of the cities in India do not have a satisfactory waste disposal system and therefore characterization of waste in each particular case is necessary to evaluate design criteria for waste management programmes.

In the present study an attempt has been made to quantify the magnitude of pollution caused by the discharge of municipal, industrial and agricultural wastes. Attempt has also been made to characterise the waste disposal of municipal and industrial origins which will be useful to evaluate design criteria for waste management programmes.

The report also presents an indirect approach for determining the load of various constituents to the river by using upstream/downstream data.

2.0 DESCRIPTION OF THE AREA

The river Kali, which flows in western districts of Uttar Pradesh (U.P), is a perennial river. It is a small water stretch having basin area of about 750 square kilometers. The river originates from Doon Vally and after routing through the districts of Saharanpur, Muzaffarnagar and Meerut, finally met with the river Hindon near village Atoli.

The area under study is part of indogangetic plains and lies between latitude 29°32′N to 29°21′30" N and longitude 77°42′ E to 77°41′15" E in the Muzaffarnagar district of Uttar Pradesh (India).

2.1 Physiography

Physiographically the area is generally flat except Siwalik hills in the north and north east. The area is devoid of relief features of any prominence except from deep gorges cut by nalas and rivers flowing through the area. The district is bound by river Yamuna in the west and river Ganga in the east.

2.2 Drainage

Regarding the drainage of the area, the rivers generally flow from north to south. These rivers during most of the non-monsoon season carry water drained into them from ground water storage. Some of the important rivers of the area are, the Ganga, Yamuna, Hindon, Krishni and the Kali(West). Apart from these rivers, the Western Ganga Canal and Eastern Yamuna Canal also drain the area.

2.3 Climate and Rainfall

The climate of the area as that of the greater part of Indian subcontinent is characterised by moderate type of subtropical monsoonic climate. In general, the average normal monsoon rainfall in the area is about 485.6 mm. The temperature ranges from 8°C in winter to 40°C in summer. Major part of the rainfall (about 75%) is received during the monsoon period. It has been observed that the rainfall is heaviest in the northern region of the district, close to foot hills of Himalayas and becomes lesser southward.

2.4 Geology

The Area under study is a part of west Indogangetic plain which is mainly composed of pleistocene and subrecent alluvium brought down by river action from the Himalayan region. In other words alluvium is made up of recent unconsolidated fluviatile formations comprising of sand, silt, clay and kankar with occasional beds of gravel. The deposits of sand beds of varying thickness are the main source of ground water in the area.

2.5 Geohydrology

The groundwater conditions in all alluvial parts are considerably influenced by the varying lithology of the subsurface formations. As the general fluviatile nature of deposits of Indogangetic plains it has been observed that the strata exhibit great variation both laterally and vertically. The main source of water which sustains groundwater body in fine to coarse grained sands is rainfall. Other sources of groundwater replenishment are infiltration from rivers, canals and return flow from irrigation, and inflow from the neighboring areas.

The most common groundwater structures in the area are shallow and deep tubewells. Dug wells are also used as source for drinking water as well as irrigation, but to a lower extent.

Based on the lithological logs and water table fluctuation data two types of aquifers have been delineated in the area (Singh et al., 1979). The upper one is the shallow unconfined aquifer which generally extends to depths around 25 m. The deeper aquifers are confined to semi-confined in nature and located at depths around 30 to 140 m, below ground level separated by three to four aquifers at average depths of 30 to 55 m, 65 to 90 m and 120 to 140 m. Water table contours in the area indicate the southward trend of ground water flow both in unconfined and confined aquifers.

2.6 Sources of Pollution

The main sources which create pollution in river Kali include, municipal waste of Muzaffarnagar city, industrial waste from variety of industries (such as steel, rubber, ceramic, chemical, plastic, dairy, pulp and paper and loundaries) and Mansurpur sugar mill and distillery waste. The wastes from variety of industries such as steel, rubber, ceramic, chemical, plastic, dairy, pulp and paper and laundries etc. transfer their wastes through Muzaffarnagar main drain into the river.

2.7 Sampling Stations

A general plan of the sampling stations with respect to different outfalls of municipal and industrial wastes in river Kali is shown in Fig. 1. The locations of main sources of pollution have also been indicated in the same figure. In all, 6 stations were selected for sampling - four from the outfalls of waste disposals and one each from upstream and downstream sections of the total stretch under study.

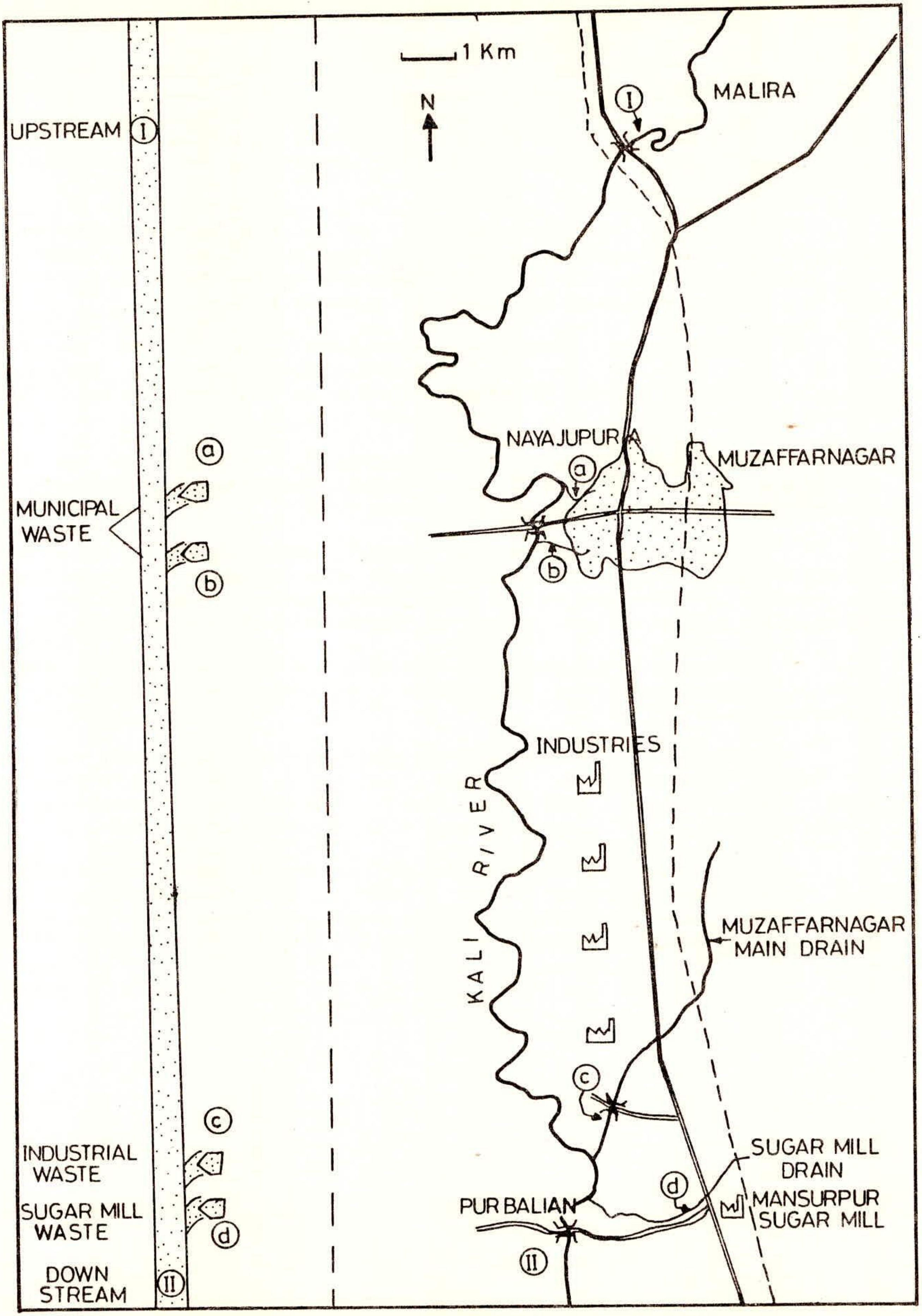

FIG. 1 GENERAL PLAN OF SAMPLING LOCATIONS

Sampling stations selected in the present study stretched over 25 km. Sampling station I and II are situated in the upstream and downstream sections of the stretch under study, while the other four stations, a to d, are located in the waste outfalls/drains in the river. Each station can be characterised as follows:

Station I (Malira bridge), is located in the relatively unpolluted river water zone near village Malira and upstream of the discharge of municipal and industrial wastes into the river. At this point the banks are high with sandy soils.

Station a (Wastewater outfall), is located in the wastewater outfall near village Nayajupura where a part of municipal waste of muzaffarnagar city is discharged into the river.

Station b (Wastewater outfall), is located in the municipal wastewater outfall near Shamli Bus stand, downstream of bridge over Muzaffarnagar-Shamli road.

Station c (Industrial drain), is located in the Main Muzaffarnagar drain, downstream of the bridge near village Begharazpur, through which the mixed waste from variety of industries and municipal areas is discharged into the river.

Station d (Sugar mill drain), is located in the sugar mill effluent drain near Mansurpur village on the National Highway.

Station II (Mansurpur bridge), is situated near village Pur Balian on Mansurpur - Shahpur road about 4 km from Mansurpur, after the outfall of sugar mill waste. The colour of the water is black and the soil is sandy mixed with some black material.

The discharge at each of the above sampling stations was determined during each visit. The temperature, pH, conductance and dissolved oxygen were measured at the site. Samples were collected and preserved for detailed analysis in the laboratory.

3.0 METHODOLOGY

3.1 Processes and Parameters

Selection of a parameter depends e.g. on its relevancy as the ease and accuracy of the measurement. The measuring frequency is determined by the expected changes in magnitude of a parameter. Continuous sampling/measuring (monitoring) is mostly desired but difficult and expensive to perform.

In chemical and biological processes several water quality parameters are involved. Measuring one or more quality parameters or (indicator) organisms give an insight about the processes which take place in the water. Some of the important processes are:

If the river bed contains chalk (limestone = $CaCO_3$ rock) and the water passing through it some CO_2, then the water will become rich in calcium bicarbonate:

$$CaCO_3 + H_2O + CO_2 = Ca(HCO_3)_2$$

Such hard waters may have the tendency to deposit $CaCO_3$ when in contact with air. The escape of CO_2 drives the equilibrium to the left. Waters that contain an excess of CO_2 are called aggressive since they corrode concrete by dissolving $CaCO_3$ (reaction to the right). Relevant parameters for this process are pH, Ca^{2+} and HCO_3^-.

In the eutrophication process, phosphates and nitrogen compounds play an important role. In combatting eutrophication it is necessary to identify the sources of these nutrients and assess their relative contributions. Point sources (e.g. domestic waste discharges) are in general easier to assess than non-point sources (e.g. run-off from agricultural land). Relevant parameters for this process are PO_4^{3-}, NH_4^+ and NO_3^-.

In fish production, recreation and agriculture, the oxygen balance and the concentration of toxic substances and of pathogens (for humans as well as for animals) play an important role. Relevant parameters are DO, toxic substances (in water and in sediment) and coliform bacteria.

The oxygen seg represents the dissolved oxygen concentration as determined by the degradation of organic matter and ammonia on the one hand and by the reaeration of the stream on the other. Characterising quality parameters for this process are BOD, COD, DO, NH_4^+ and NO_3^-.

Water flow and reaeration determine the capacity of the river to resist pollution by dilution and self-purification. Relevant parameters are wet cross-section, flow velocity, Cl^- (a conservative constituent of which the concentration only changes by dilution and evaporation and not by degradation). Reaeration is a function of flow velocity and depth and is also affected by wind and the presence of weirs.

Although conductivity is only an overall indication of the total salt concentration and is affected by pH, it may be useful in identifying unexpected discharges. It can also be employed in determining river flows by means of tracers consisting of salts.

3.2 Sampling and Preservation

For the pollution survey of the river, six sampling stations were chosen as described in the previous chapter.

Monthly samples of the river water and effluents were collected for one year (January to December 1992) by dip (or grab) sampling method. The discharge at all the six sampling stations was also determined during each visit.

The water and wastewater samples were collected from mid stream at about six inches depth and subjected to various physico-chemical tests. The samples thus collected were stored in clean plastic bottles fitted with screw caps. Some parameters like temperature, pH and electrical conductance were measured on the spot by means of portable meters. For other parameters, samples were preserved by adding an appropriate reagent. The samples thus preserved were stored at 4°C in sampling kits and brought to the laboratory for detailed analysis.

For complete sampling at a point the following bottles were filled:

i) One bottle of 500 mL for direct measurement of pH, conductivity and temperature at site.

ii) One BOD bottle of 300 mL for dissolved oxygen. Dissolved oxygen was fixed at site by adding 1.0 mL of manganous sulphate reagent followed by 1.0 mL of alkaline-iodide-azide solution.

iii) one bottle of 500 mL for laboratory analysis of nitrate and ammonia. Sample was preserved by adding 0.8 mL conc. sulfuric acid per liter.

iv) One bottle of 1000 mL for acidity/alkalinity, BOD, calcium, chloride, COD, hardness, magnesium, phosphate, sodium, sulphate, turbidity and potassium.

3.3 Measurement and Methods

3.3.1 Physical and chemical parameters

Physico-chemical analysis were conducted following Standard Methods for the Examination of Water and Waste water (1985). Temperature, pH and electrical conductance were determined in the field at the time of sample collection using portable meters. Turbidity was examined by HACH turbidity meter.

Chloride was estimated by argentometric method in the form of silver chloride. Alkalinity was determined by titrimetric method using phenolphthalein and methyl orange indicator.

Total hardness and calcium hardness were determined by EDTA titrimetric method while magnesium hardness was calculated by deducting calcium hardness from total hardness. Calcium (as Ca^{++}) was calculated by multiplying calcium hardness with 0.401 while magnesium (as Mg^{++}) by multiplying magnesium hardness with 0.243.

Nitrogen in the form of ammonia and nitrate was determined by using ion-specific electrodes.

Sodium and potassium were determined by flame-emission method using flame photometer.

Phosphate was estimated by stannous chloride method in the form of molybdenum blue while sulphate by turbidimetric method in the form of barium sulphate crystals.

The summary of analytical methods and equipment used in the study are given in Table 1.

3.3.2 Hydrometric parameters - load, water flow and velocity

Load (L) of a particular substance is calculated by using the formula:

$$L = Q \cdot C$$

where Q = flow, and
C = concentration

The flow (Q) of a water course is measured via the water velocity by means of the formula:

$$Q = \bar{v} \cdot A$$

where $\bar{v}$ = mean velocity, and
A = cross-sectional area

In this case the cross-sectional area (A) is measured and the mean velocity is determined by measuring the time (t) needed for a float to reach a certain point:

$$v = S/t$$

where S = distance between two points.

Table 1.' Summary of Analytical Methods and Equipment Used in the Study

Parameter	Analytical method	Equipment used
pH	Electrometric	pH meter (WTW)
Conductivity	Wheatstone bridge	Conductivity meter
Temperature	Thermometric	pH meter (WTW)
Turbidity	Photometric	Turbidity meter (HACH Model 16800)
Solids	Gravimetric	-
Alkalinity	Titrimetric	-
Hardness	Titrimetric	-
DO	Iodometric	-
BOD	Dilution	BOD Incubator (Calton)
COD	Dichromate	COD Digestion System (Tecator)
Calcium	Titrimetric	-
Magnesium	Titrimetric	-
Chloride	Mercuric nitrate	-
Sulphate	Turbidimetric	Turbidity meter (HACH Model 16800)
Phosphate	Ascorbic acid	Spectrophotometer (Milton Roy)
Ammonia-nitrogen	Ion-selective electrode	Ion-analyser (Radio Meter Ion-83)
Nitrate-nitrogen	Ion-selective electrode	Ion-Analyser (Radio Meter Ion-83)
Sodium	Flame-emission	Flame photometer (Toshniwal RL 01.02)
Potassium	Flame-emission	Flame photometer (Toshniwal RL 01.02)

4.0 RESULTS AND DISCUSSION

The quality of river water as determined by the geological character of the catchment area as well as the various sources of pollution generated by domestic, agricultural and industrial wastes in the region, is of great importance in determining its suitability for a particular use.

Presence of some constituents, beyond a certain limit make the water injurious for irrigation, drinking or industrial purposes. Water should therefore meet the standards for the specific use to which it is put.

In order to see the effect of waste disposals on the quality of water of river Kali, a number of quality parameters (physical and chemical) have been determined at selected points (Fig. 1) by direct measurement on the spot, or later in the laboratory after taking samples.

The study has been conducted for one year (January to December 1992). Flow values determined at different sampling stations are given in Table 2. The increase in flow between stations I and II is brought about by the outfalls of municipal waste at Muzaffarnagar, combined industrial waste through Muzaffarnagar main drain and Mansurpur sugar mill waste. Effluent samples, collected from the municipal waste, combined industrial waste from variety of industries (such as steel, rubber, ceramic, chemical, plastic, dairy, pulp and paper and laundries) and sugar mill waste, were characterized for various water quality parameters and the results are discussed below.

4.1 Sources, Volume and Characteristics of the Wastes

The main sources which create pollution in river Kali include, municipal waste of Muzaffarnagar city, industrial waste from variety of industries (such as steel, rubber, ceramic, chemical, plastic, dairy, pulp and paper and loundaries) and Mansurpur sugar mill and distillery waste. The wastes from variety of industries transfer their wastes into the river through main Muzaffarnagar drain.

4.1.1 Characteristics of municipal waste

The major portion of the municipal wastewater of Muzaffarnagar city flows through a system of open nalas and is discharged into the river at two points. One having an average wastewater discharge of 0.315 cumecs. is discharged into the river near village Nayajupura while another part of the waste having almost the same flow is discharged near Shamli bus stand, downstream of the bridge. At both the points, lot of people and domestic animals (cows and buffalos) take bath and cloth washing activities are common just upstream of the outfalls of the municipal waste. From the point of view of pollution of the river and the deterioration of water quality in the bathing areas, the discharge from these drains have been most critical. The physico-chemical characteristics of the waste collected from both the locations were determined and are given in Table 3 & 4 respectively.

The variation in pH at both the locations (Table 3 & 4) indicate that there is not much fluctuation in pH of municipal wastes at the two locations. The average values of alkalinity observed at the two locations indicate that the waste discharged near Shamli bus stand is slightly more alkaline than waste discharged near village Nayajupura. The alkalinity values vary from 268 to 449 mg/L near village Nayajupura and 310 to 522 mg/L at downstream of the bridge near Shamli bus stand.

The total solid contents are also very high, ranging from 1864 to 2023 mg/L near village Nayajupura and from 2052 to 2359 mg/L near Shamli bus stand with an average value of 1904 and 2062 mg/L at the two locations respectively.

The average conductivity value was found to be 1355 uS/cm near village Nayajupura with minimum value of 957 uS/cm and maximum value of 1662 uS/cm.

The average chloride content in the municipal waste water discharged near village Nayajupura was found to be 87.6 mg/L with a minimum value of 71 mg/L in the month of August and a maximum value of 106 mg/L in the month of June. The same trend was also found in the wastewater discharged near Shamli bus stand.

The average value of sulphate and phosphate were found to be 45.6 and 2.17 mg/L respectively in the wastewater discharged near village Nayajupura while the content of these two parameters were found to be 50.9 and 2.28 mg/L in the wastewater discharged near Shamli bus stand.

The average values of nitrate and ammonia were found to be 6.00 and 15.1 mg/L respectively in the wastewater discharged near village Nayajupura and 6.04 and 16.8 mg/L in the wastewater discharged near Shamli bus stand.

The dissolved oxygen content in the waste is very low (< 1.0 mg/L) at both the locations. The BOD values of the waste are very high, ranging from 297 to 628 mg/L near village Nayajupura and from 291 to 638 mg/L near Shamli bus stand. The COD values varies from 370 to 799 mg/L near village Nayajupura and 373 to 806 mg/L at downstream of the bridge near Shamli bus stand. Such high values of BOD and COD clearly indicate large scale disposal of untreated wastewater into the river.

It can be observed from the results that the discharge of municipal wastewater into the river would be hazardous due to the high values of biochemical oxygen demand, chemical oxygen demand and other parameters.

4.1.2 Characteristics of industrial waste

The combined effluent coming from variety of industries is usually blackish in colour and has pungent and irritating smell. This waste flows through the main drain into the river. Due to the presence of various chemicals and other alkaline mixtures, a soapy and fibrous froth is continuously generated in the waste. A dirty black soil is also visible in the area. The physico-chemical characteristics of this composite waste was studied and the results are presented in Table 5.

The determination of pH serves as a valuable index which shows whether the waste is acidic or alkaline in nature. It also gives some idea about the extent of pollution. The pH of the composite waste was always towards alkaline side and vary from 7.1 to 7.3 (Table 5).

The total solids content in the composite waste was very high, ranging from 975 to 1166 mg/L with an average value of 1076 mg/L. The conductivity value varies from 1010 to 1265 uS/cm with an average value of 1107 uS/cm. The maximum value of conductivity was observed in the month of June while minimum value was obtained in the month of August.

The average value of alkalinity was found to be 652 mg/L with a minimum value of 539 mg/L in the month of September and maximum value of 797 mg/L in the month of June.

The dissolved oxygen content in the waste is altogether absent in all the months. The BOD and COD values of the composite waste are very high and ranges from 309 to 637 mg/L and 412 to 853 mg/L respectively.

The composite waste also contain high concentration of sodium and potassium. The average value of sodium in the waste was found to be 191 mg/L with a minimum value of 121 mg/L and maximum value of 269 mg/L. The average value of potassium was found to be 32.4 mg/L with a minimum value of 21 mg/L and maximum value of 48 mg/L.

The content of nitrate in the waste varies from 10.3 to 14.7 mg/L with an average value of 12.4 mg/L.

It is obvious from the study that the treatment of industrial effluents is necessary before discharging them into the river.

4.1.3 Characteristics of sugar mill waste

The sugar factories generally employ double carbonation and double sulphitation processes for the manufacture of sugar from the sugar cane. The volume and the characteristics of the sugar factory waste arising from the different operations vary largely, depending on the availability of the cane, water and size of the plant.

The distillery mainly manufacture rectified spirit, methylated spirit and alcohol from molasses, which is a cheap source for alcohol production. Here the molasses are first diluted with water to bring the sugar content between 8 to 10 percent. This dilution is necessary as the yeast cells can not grow at higher concentrations. Small amounts of ammonium sulphate and ammonium phosphate are added as a source of nitrogen for the growth of yeast cells. This solution is acidified with a small amount of sulphuric acid. After the fermentation takes place, the contents are put into distillation column where the alcohol get separated.

The physico-chemical characteristics of the mixed waste from Mansurpur sugar mill and distillery are shown in Table 6. The composite effluent flows through an open channel and opens on the left bank of river Kali.

The temperature of the sugar mill waste varies between 28.0 to 38.2 ^{o}C. It has been observed that high temperature decreases the oxygen solubility of water and increase the rate of chemical reactions. High temperature also affects the BOD and its value becomes very high due to increased metabolic activity of bacteria.

The composite waste is usually light brown in colour with aromatic in smell. The dissolved oxygen content in the waste is altogether absent. The BOD and COD values of the waste are very high ranging from 982 to 1414 mg/L and from 1512 to 1913 mg/L respectively. The content of total solids are also very high ranging between 4256 to 5372 mg/L.

The presence of cane fibres and high suspended solids in the sugar mill and distillery waste may clog the gills of the fishes and hamper the normal gaseous exchange. Similar findings have been reported by Verma and Mathur (1971) for paper mill waste containing fine colloidal particles of lignin and cellulose.

It can be observed from Table 3 to 6 that the discharge of the municipal, industrial and sugar mill waste into the river would be hazardous due to the high values of biochemical oxygen demand, chemical oxygen demand and total solids in the waste. If wastes containing high BOD and COD find their way into the river, these are known to cause a heavy depletion in oxygen levels in the particular sector of the river (Verma and Shukla, 1969; Verma and Mathur, 1971; Mohanrao, 1972).

It is obvious from the study that the treatment of effluent is necessary before discharging them into the river. Treatment needs will be minimum if the waste is disposed off in sewerage and maximum if it is disposed off in rivers.

4.2 River Water Quality at Upstream and Downstream Sections

In order to see the effect of waste disposals on the quality of water of the river, the water samples were collected from upstream and downstream sections and analysed for various physico-chemical parameters. Table 7 and 8 contains the results of analysis for upstream and downstream sections respectively. The monthly variation of various parameters at upstream and downstream sections are presented in Figs. 2 to 21. It is clearly evident from the figures that there are considerable variations in the concentrations of various constituents with time.

In general, it is evident from the data that concentration of most of the parameters were higher during summer in comparison to monsoon and winter. This is due to the low flow in the river during summer months. During the rains, however, considerable dilution of the river water occurs due to runoff from the land as well as through direct channel precipitation.

An examination of Fig. 2 indicate that the temperature values are on higher side in the downstream section in comparison to upstream section. This is because of the mixing of sugar mill waste which is having higher temperature. The higher temperature in the downstream section may also be probably due to the collection of downstream samples in the noon.

The pH of the river water at both upstream and down stream sections was always found towards alkaline side. However, the variations in pH at upstream and downstream sections were not appreciable. The pH value ranges between 7.6 to 7.7 at upstream section and 7.2 to 7.3 at downstream section. The lower values of pH in the downstream section is due to the mixing of sugar mill waste which is acidic in nature. The determination of pH serves as a valuable index which shows whether the pollution is from acidic or alkaline wastes. It also gives some idea about the extent of pollution.

The turbidity of river water varies from 17 to 30 NTU in the upstream section and 41 to 55 NTU in the downstream section. The higher values of turbidity in the downstream section are due to the discharges of municipal and industrial wastes which carries large quantities of suspended matter. Turbidity of the water have direct effect on the light penetration and thus affect the bottom conditions, plankton and bacterial concentration of the water.

The water is transparent in the upstream section while it is blackish in the downstream section due to the mixing of sugar mill and industrial wastes. The sugar mill effluent stagnates in the drain and stream for a long time, because of which the biological action starts and obnoxious condition soon develops in the region. This septic condition results in the production of hydrogen sulphide gas imparting black colour to the effluent and the stream water.

The total solids content varies from 213 to 382 mg/L in the upstream section and 380 to 710 mg/L in the downstream section. The maximum concentration of total solids was recorded in the month of July both at upstream and downstream sections (Fig.8). The maximum concentration of total dissolved solids was also recorded in the month of July whereas minimum value was recorded in the month of September both at upstream and downstream sections (Fig. 6).

The maximum conductivity values were obtained in the month of June, whereas the minimum values were obtained in the month of September both at upstream and downstream sections (Fig. 4).

The average chloride content of the river water is only 9.1 mg/L in the upstream section and 30 mg/L in the downstream section (Table I and II). This increase in chloride content can be attributed to the addition of municipal and industrial wastes into the river. Limits to chloride content have been laid down primarily from taste considerations (Handa, 1977; 1985). No adverse health effects on humans have been reported from intake of waters containing even 600-1000 mg chloride per liter.

The average alkalinity value in the upstream section was 199 mg/L, with maximum value of 278 mg/L and minimum value of 143 mg/L (Table I). The average value of alkalinity in the downstream section was 268 mg/L, with maximum value of 338 mg/L and minimum value of 205 mg/L (Table II). It is further evident from Fig. 9, that as expected it is during the rainy seasons that the lowest values are obtained for this parameter.

The dissolved oxygen condition in the upstream section was quite satisfactory (7.0 to 7.7 mg/L), but a critical situation was observed in the downstream section (2.1 to 3.0 mg/L). The sudden fall in dissolved oxygen (Fig. 10) and abrupt rise in BOD (Fig. 11) in the downstream section is attributed to the discharge of untreated municipal and industrial wastes in the river. The BOD value ranges from 15 to 28 mg/L in the upstream section and 94 to 130 mg/L in the downstream section. The COD value varies from 20 to 40 mg/L in the upstream section and 112 to 169 mg/L in the downstream section. It may be stated that maximum value of BOD for potable water is 2 mg/L and that for bathing is 3 mg/L. The higher values of BOD and COD observed both in the upstream and downstream sections indicate high degree of pollution and is not suitable for domestic purposes.

From the general distribution of D.O. and oxygen consumed from station I to II, it appears that the wastes discharged into the river are being oxidised and the rate of oxygen replenishment in the water is lower than the oxygen utilisation. This is clearly evident by the depletion of oxygen from station I to II. Deoxygenation generally occurs as a result of breakdown of organic matter by bacterial activity and therefore the discharge of municipal and industrial wastes into the river at regular intervals do not allow any self purification to occur.

The average sodium ion concentration in the upstream section was 22.3 mg/L, with maximum value of 31 mg/L and minimum value of 18 mg/L (Table I). The average value of sodium in the downstream section was 49.2 mg/L, with maximum value of 62 mg/L and minimum value of 41 mg/L (Table II). Monthly variation in the concentration of sodium ions at upstream and downstream section is shown in Fig. 18. The increase in sodium content in the downstream section may be attributed to the contribution from sewage and other waste effluents entering the river.

The average potassium content in the upstream section was 5.0 mg/L while in the downstream section it was 19.8 mg/L. This increase in potassium content may be attributed due to contributions from runoff from agricultural lands (dressed with potassic fertilizers) and waste effluents.

The above observations clearly indicates that the river Kali is grossly polluted. The colour of the water is blackish and it emits an unpleasant odour. Most of the wastes discharged into the river seems to be of organic nature.

4.3 Mass Balance to Upstream/Downstream River Water quality Data

One of the most important aspect of water quality engineering is the determination of the input mass loading, that is, the total mass of a material discharged per unit time into a specific body of water. For defined sources with continuous flow, the input load is given by the equation:

$$L(t) = Q(t)\,C(t)$$

Where C(t) is the concentration of the input [M/L^3], Q(t) is the input flow [L^3/T] and L(t) is the mass rate (load) of input [M/T], all quantities occurring simultaneously at given time t. In metric units, the concentration and flow are often expressed in mg/L and m^3/s respectively. Also, for almost all practical purposes;

$$1 \text{ mg/L} = 1 \text{ g/m}^3 = 10^{-3} \text{ kg/m}^3$$

Then,

$$L = Q \cdot C$$

Where L is in g/s, Q in m^3/s and C in mg/L (= g/m^3)

The basic idea in describing the discharge of material into a river is to write a mass balance equation for various reaches of the river. The principal statement for the mass balance assuming complete mixing is:

Load of substance upstream + Load added by outfalls

= Load of substance immediately downstream from outfall

Recalling that the load is the product of flow and concentration, the mass balance is therefore given by:

$$Q_U C_U + \sum_{i=1}^{n} L_i = Q_D C_D$$

Where Q_U and Q_D are upstream and downstream flows,

C_U and C_D are upstream and downstream concentrations in the receiving water,

and $\sum_{i=1}^{n} L_i$ is the sum of all individual loadings to the receiving water.

For understanding the relationship between the water quality found and the sources of natural and man-made pollution, the drawing up of mass balance for certain water constituents is of great help. This is done by determining the load of selected substances, i.e. the weight of the substance transported through a cross-section of the river bed per second.

When two or more rivers come together at one point, the sum of the loads carried by the streams above the confluence must be equal to the load of the river downstream of this point. This enables us to check the measurements done.

The mass balance for some constituents for river Kali have been drown by multiplying average values of flow with average values of the particular constituents (Table 9) and the results are presented in Table 10. It can be argued from the results that the changes found in load along the river may be mainly due to the contribution of non-point sources of pollution. The difference may also be attributed to some small point sources of pollution which could not be identified in the course of investigations.

Table 2. Flow Values Through Various Sampling Stations

Station	Flow Values ($m^3 s^{-1}$)		
	Minimum	Maximum	Average
I. Malira Bridge	3.28	6.12	4.324
a) Wastewater Outfall Near Village Nayajupura	0.28	0.47	0.315
b) Wastewater Outfall Near Shamli Bus Stand	0.23	0.46	0.318
c) Industrial Drain	0.32	0.80	0.500
d) Sugar Mill Drain	0.16	0.37	0.245
II. Mansurpur Bridge	5.00	7.70	6.026

Table 3. Physico-chemical Characteristics of Municipal Wastewater Near Village Nayajupura

Characteristics	Values		
	Minimum	Maximum	Average
Temperature, °C	16.2	28.8	23.7
pH	7.1	7.3	7.2
Conductance, uS/cm	957	1662	1355
Turbidity, NTU	73	86	79
Dissolved solids, mg/L	633	992	833
Suspended solids, mg/L	867	1247	1071
Total solids, mg/L	1500	2239	1904
Alkalinity, mg/L	268	449	360
Dissolved oxygen, mg/L	Nil	0.5	0.2
BOD, mg/L	297	628	446
COD, mg/L	370	799	550
Chloride, mg/L	71	106	87.6
Sulphate, mg/L	38	63	45.6
Phosphate, mg/L	2.00	2.38	2.17
Nitrate, mg/L	5.0	7.8	6.0
Ammonia, mg/L	12.4	18.9	15.1
Sodium, mg/L	58	121	79.9
Potassium, mg/L	21	55	36.5
Calcium, mg/L	63	101	80.8
Magnesium, mg/L	16	39	26.8

Table 4. Physico-chemical Characteristics of Municipal Wastewater Near Shamli Bus Stand

Characteristics	Values		
	Minimum	Maximum	Average
Temperature, °C	18.1	28.8	24.4
pH	7.2	7.4	7.3
Conductance, uS/cm	1141	1910	1555
Turbidity, NTU	85	99	92
Dissolved solids, mg/L	777	1160	970
Suspended solids, mg/L	761	1353	1092
Total solids, mg/L	1538	2513	2062
Alkalinity, mg/L	310	531	424
Dissolved oxygen, mg/L	Nil	0.6	0.3
BOD, mg/L	291	638	447
COD, mg/L	368	806	571
Chloride, mg/L	69	115	92.5
Sulphate, mg/L	37	81	50.9
Phosphate, mg/L	1.80	2.70	2.28
Nitrate, mg/L	5.0	7.7	6.04
Ammonia, mg/L	14.5	20.8	16.8
Sodium, mg/L	61	131	86.9
Potassium, mg/L	23	64	43.2
Calcium, mg/L	65	101	84.2
Magnesium, mg/L	18	43	30.5

Table 5. Physico-chemical Characteristics of Combined Industrial Waste

Characteristics	Values		
	Minimum	Maximum	Average
Temperature, °C	20.7	31.9	26.8
pH	7.1	7.3	7.2
Conductance, uS/cm	1010	1265	1107
Turbidity, NTU	127	148	134
Dissolved solids, mg/L	644	820	707
Suspended solids, mg/L	331	476	369
Total solids, mg/L	975	1296	1076
Alkalinity, mg/L	539	797	652
Dissolved oxygen, mg/L	Nil	Nil	Nil
BOD, mg/L	309	637	456
COD, mg/L	412	853	616
Chloride, mg/L	52	100	68
Sulphate, mg/L	43	85	57.8
Phosphate, mg/L	0.50	0.77	0.64
Nitrate, mg/L	10.3	14.7	12.4
Ammonia, mg/L	9.1	12.9	10.9
Sodium, mg/L	121	269	191
Potassium, mg/L	21	48	32.4
Calcium, mg/L	61	108	78.3
Magnesium, mg/L	16	29	20.6

Table 6. Physico-chemical Characteristics of Mansurpur Sugar Mill Waste

Characteristics	Values		
	Minimum	Maximum	Average
Temperature, °C	28.0	38.2	31.6
pH	6.2	6.3	6.3
Conductance, uS/cm	2790	3830	3468
Turbidity, NTU	186	192	188
Dissolved solids, mg/L	1698	2015	1852
Suspended solids, mg/L	2558	3357	3056
Total solids, mg/L	4256	5372	4909
Alkalinity, mg/L	830	1197	1007
Dissolved oxygen, mg/L	Nil	Nil	Nil
BOD, mg/L	982	1414	1275
COD, mg/L	1512	1913	1765
Chloride, mg/L	123	201	169
Sulphate, mg/L	118	200	166
Phosphate, mg/L	1.00	2.00	1.56
Sodium, mg/L	118	198	164
Potassium, mg/L	154	259	202
Calcium, mg/L	176	251	214
Magnesium, mg/L	29	46	35.1

Table 7. Physico-chemical Characteristics of River Water at Upstream Section

Characteristics	Values		
	Minimum	Maximum	Average
Temperature, °C	16.4	29.4	23.8
pH	7.6	7.7	7.6
Conductance, uS/cm	290	500	402
Turbidity, NTU	17	30	21
Dissolved solids, mg/L	185	340	268
Suspended solids, mg/L	23	42	32
Total solids, mg/L	213	382	300
Alkalinity, mg/L	143	278	199
Dissolved oxygen, mg/l	7.0	7.7	7.5
BOD, mg/L	15	28	22
COD, mg/L	20	41	31
Chloride, mg/L	6.0	15	9.1
Sulphate, mg/L	13	26	18.7
Phosphate, mg/L	0.15	0.32	0.22
Nitrate, mg/L	1.60	2.60	1.96
Ammonia, mg/L	0.20	0.40	0.30
Sodium, mg/L	18	31	22.3
Potassium, mg/L	5.0	6.0	5.0
Calcium, mg/L	33	69	48.8
Magnesium, mg/L	11	20	15.1

Table 8. Physico-chemical Characteristics of River Water at Downstream Section

Characteristics	Values		
	Minimum	Maximum	Average
Temperature, °C	18.8	31.1	25.6
pH	7.2	7.3	7.3
Conductance, uS/cm	430	780	587
Turbidity, NTU	41	55	46
Dissolved solids, mg/L	250	490	364
Suspended solids, mg/L	130	225	176
Total solids, mg/L	380	710	540
Alkalinity, mg/L	205	338	268
Dissolved oxygen, mg/L	2.1	3.0	2.7
BOD, mg/L	94	130	111
COD, mg/L	112	169	141
Chloride, mg/L	20	41	30
Sulphate, mg/L	20	46	31
Phosphate, mg/L	0.37	0.66	0.51
Nitrate, mg/L	3.10	4.00	3.41
Ammonia, mg/L	1.80	2.65	2.18
Sodium, mg/L	41	62	49.2
Potassium, mg/L	13	33	19.8
Calcium, mg/L	48	78	59.8
Magnesium, mg/L	13	26	19.3

Table 9. Average Values of Flow and Some Water Quality Constituents at Different Sampling Stations

Station	Flow ($m^3 s^{-1}$)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)
I. Upstream Section	4.324	22.3	5.0	48.8	15.1
a) Waste Water Outfall Near Village Nayajupura	0.315	79.3	36.5	80.8	26.8
b) Waste Water Outfall Near Shamli Bus Stand	0.318	86.9	43.2	84.2	30.5
c) Industrial Drain	0.500	191	32.4	78.3	20.6
d) Sugar Mill Drain	0.245	164	202	204	35.1
II. Downstream Section	6.026	49.2	19.8	59.8	19.3

Station	Flow ($m^3 s^{-1}$)	Cl (mg/L)	SO_4 (mg/L)	PO_4 (mg/L)
I. Upstream Section	4.324	9.1	18.7	0.22
a) Waste Water Outfall Near Village Nayajupura	0.315	87.6	45.6	2.17
b) Waste Water Outfall Near Shamli Bus Stand	0.318	92.5	50.9	2.28
c) Industrial Drain	0.500	68.0	57.8	0.64
d) Sugar Mill Drain	0.245	169	166	1.56
II. Downstream Section	6.026	30.0	31.3	0.51

Table 10. Loadings and Mass Balance Calculations for Various Constituents

Station	Load (kg D^{-1}) Na	K	Ca	Mg
I. Upstream Section	8331	1868	18231	5641
a) Waste Water Outfall Near Village Nayajupura	2175	1007	2199	729
b) Waste Water Outfall Near Shamli Bus Stand	2388	1187	2313	838
c) Industrial Drain	8251	1400	3383	890
d) Sugar Mill Drain	3472	4276	4318	743
Sum { I + (a to d) }	24617	9738	30444	8841
II. Downstream Section	25616	10309	31135	10048

Station	Load (kg D^{-1}) Cl	SO_4	PO_4
I. Upstream Section	3400	6986	82
a) Waste Water Outfall Near Village Nayajupura	2384	1241	59
b) Waste Water Outfall Near Shamli Bus Stand	2541	1398	63
c) Industrial Drain	2938	2496	28
d) Sugar Mill Drain	3577	3514	33
Sum { I + (a to d) }	14840	15635	265
II. Downstream Section	15619	16296	266

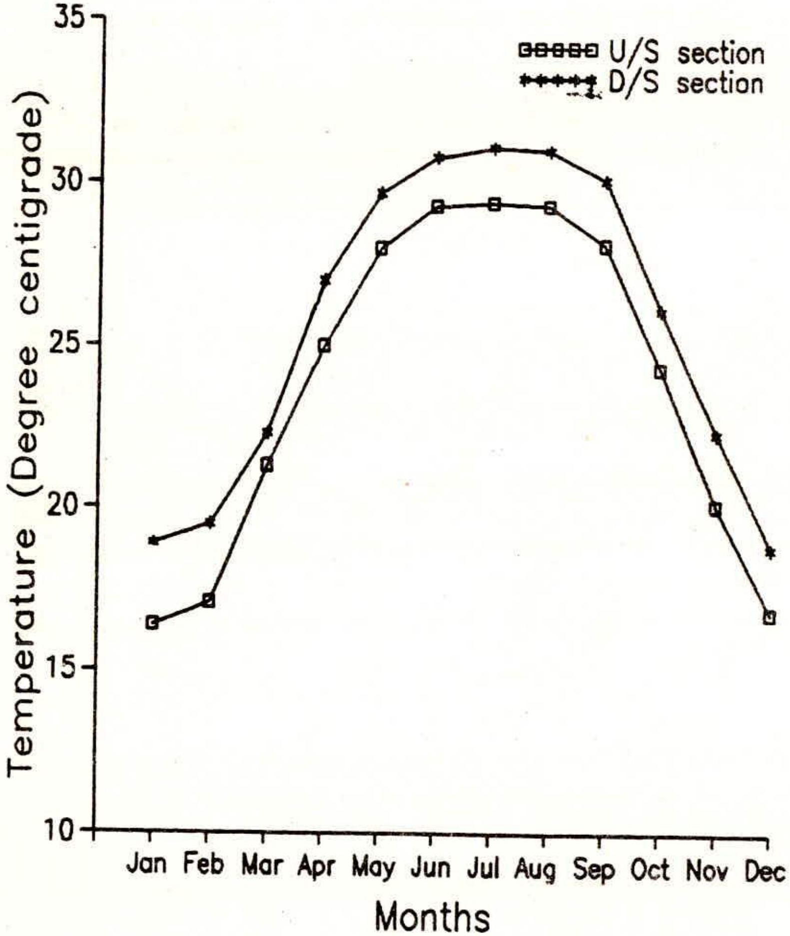

Fig. 2 Monthly variation of temperature at U/S and D/S sections in river Kali.

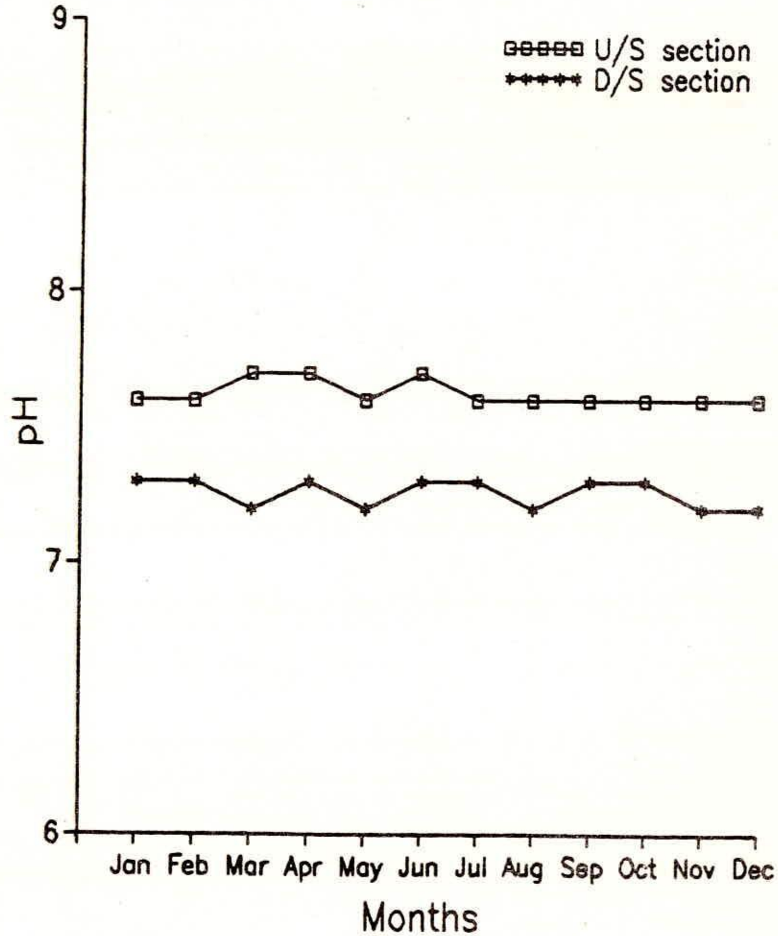

Fig. 3 Monthly variation of pH at U/S and D/S sections in river Kali.

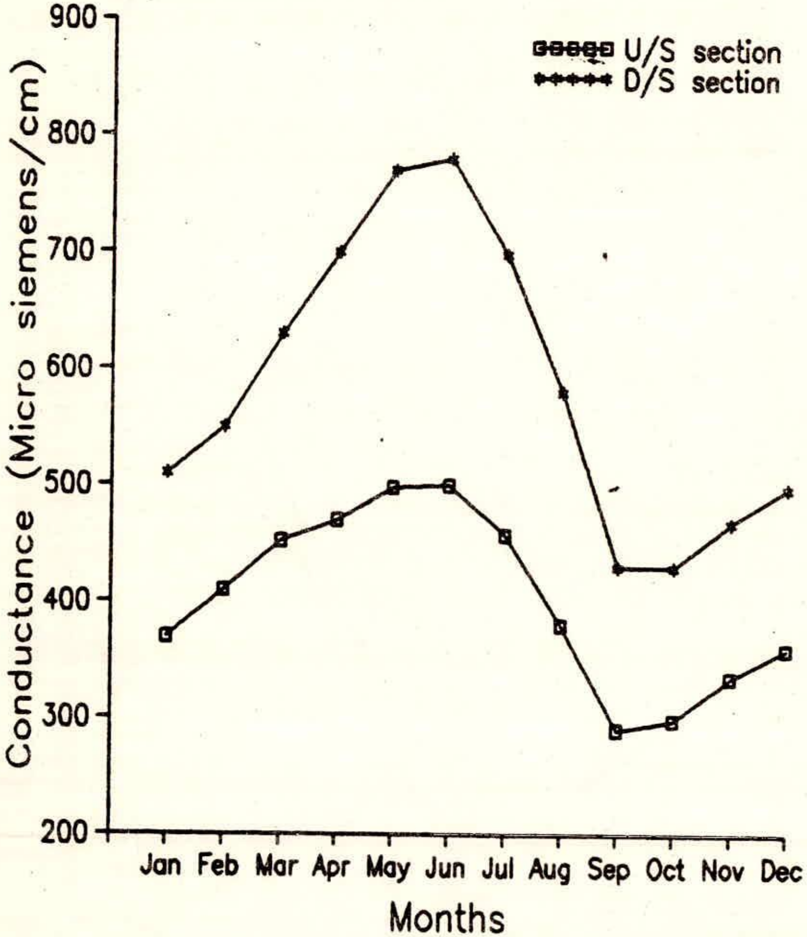

Fig. 4 Monthly variation of conductance at U/S and D/S section in river Kali.

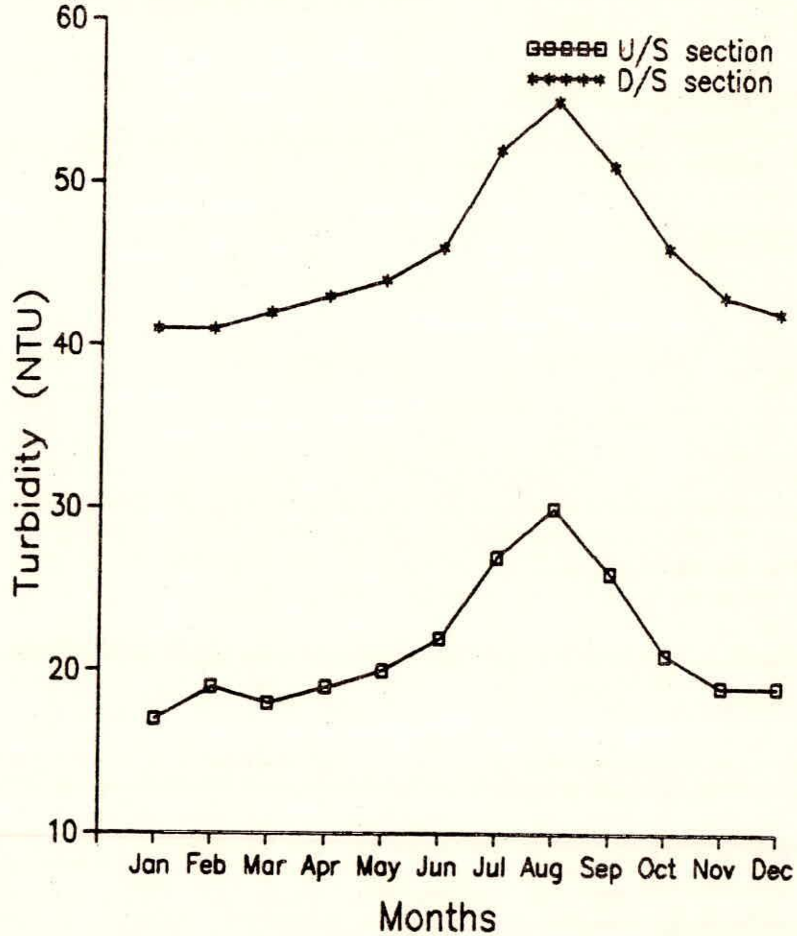

Fig. 5 Monthly variation of turbidity at U/S and D/S section in river Kali.

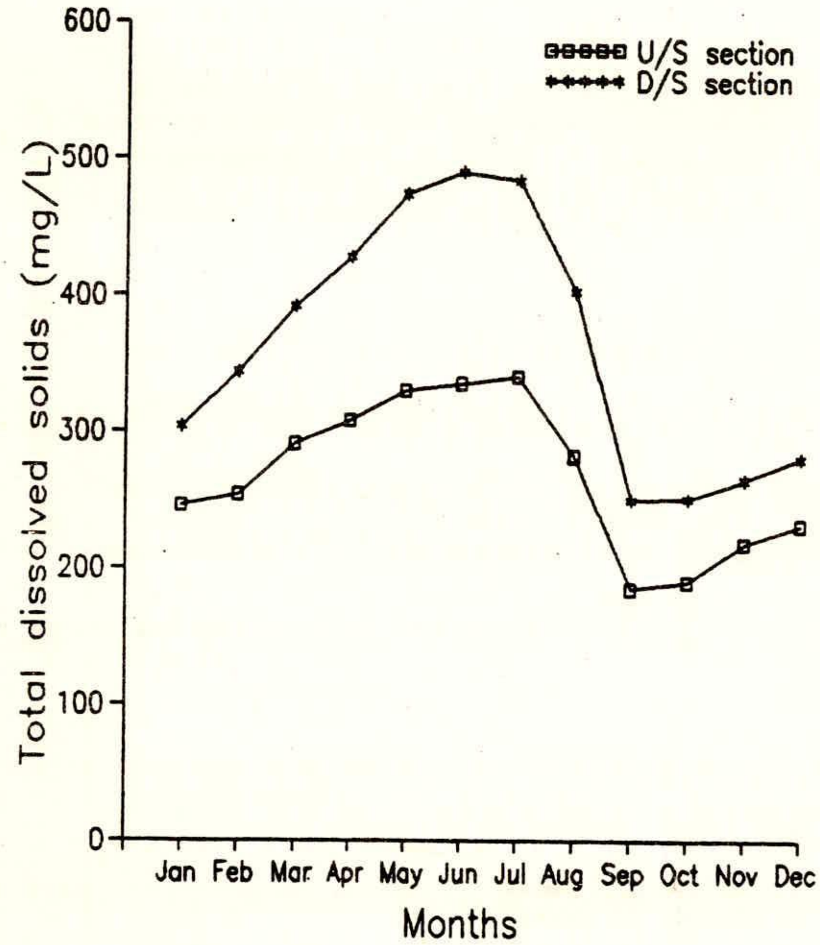

Fig. 6 Monthly variation of total dissolved solids at U/S and D/S sections in river Kali

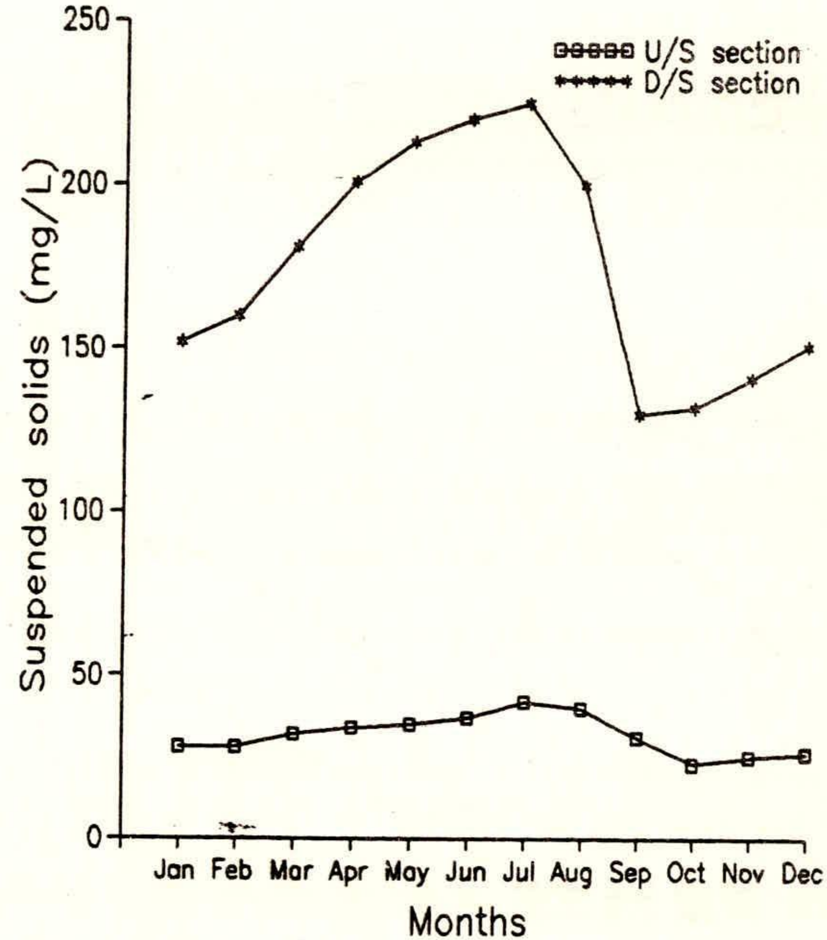

Fig. 7 Monthly variation of suspended solids at U/S and D/ sections in river Kali

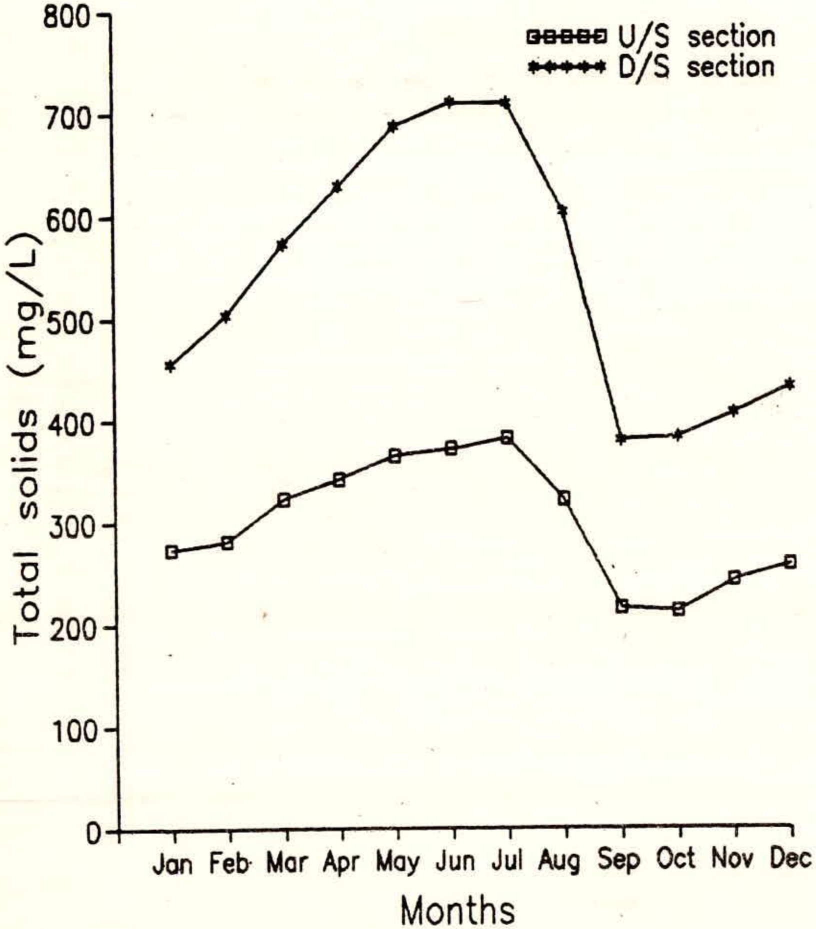

Fig. 8 Monthly variation of total solids at U/S and D/S section in river Kali

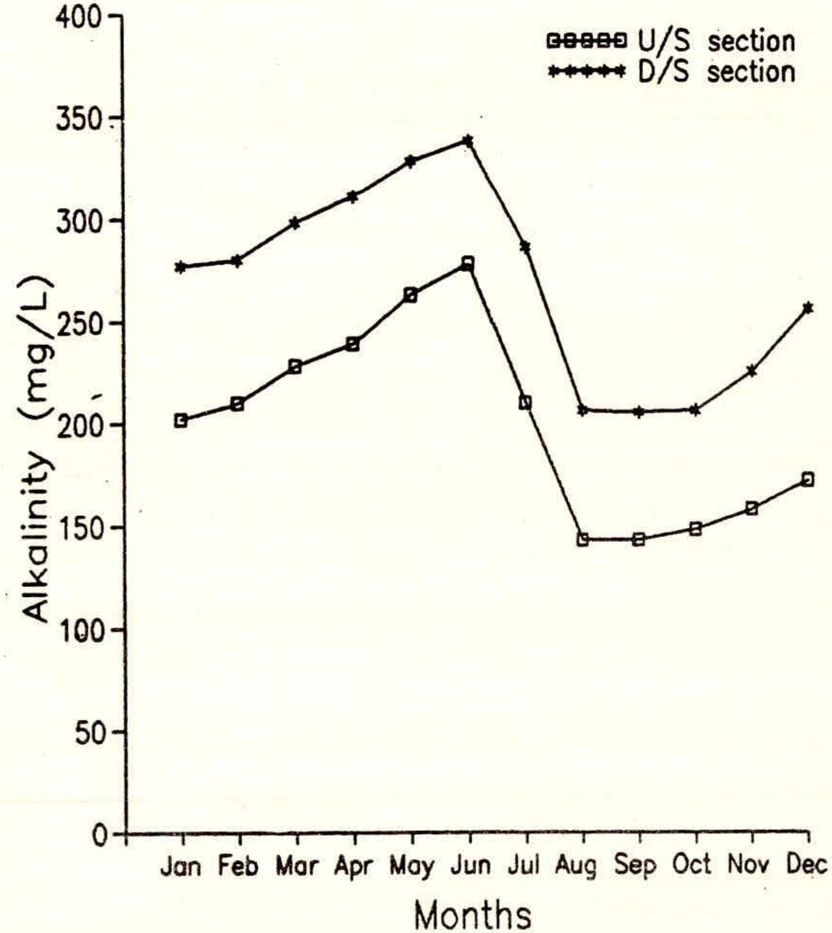

Fig. 9 Monthly variation of alkalinity at U/S and D/S section in river Kali

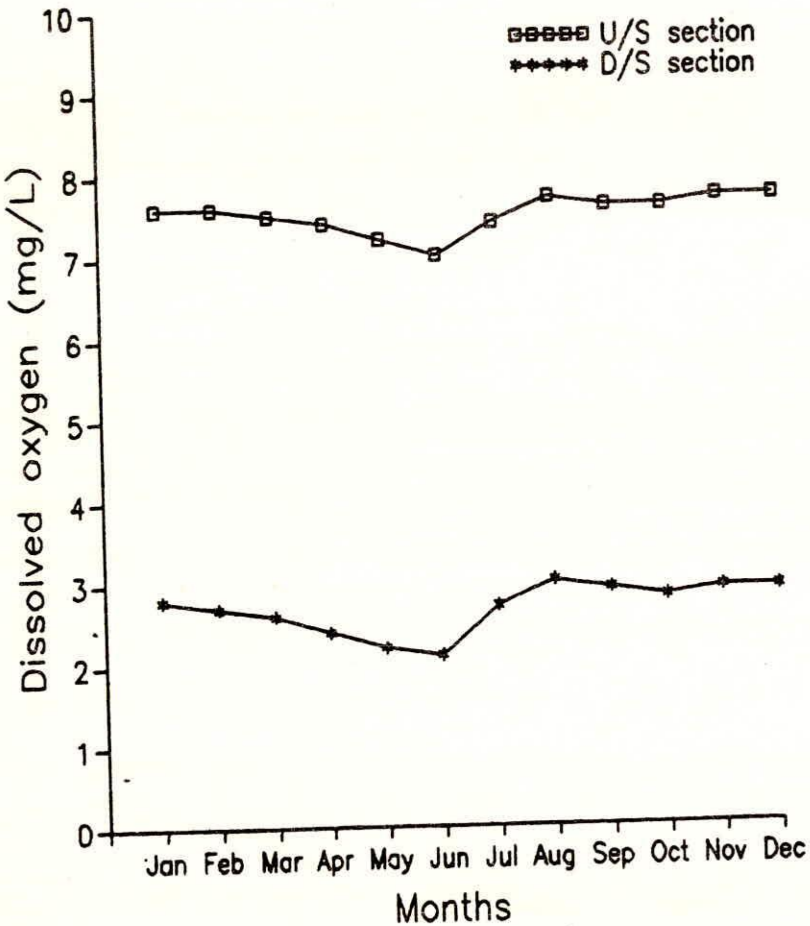

Fig. 10 Monthly variation of dissolved oxygen at U/S and D/S sections in river Kali

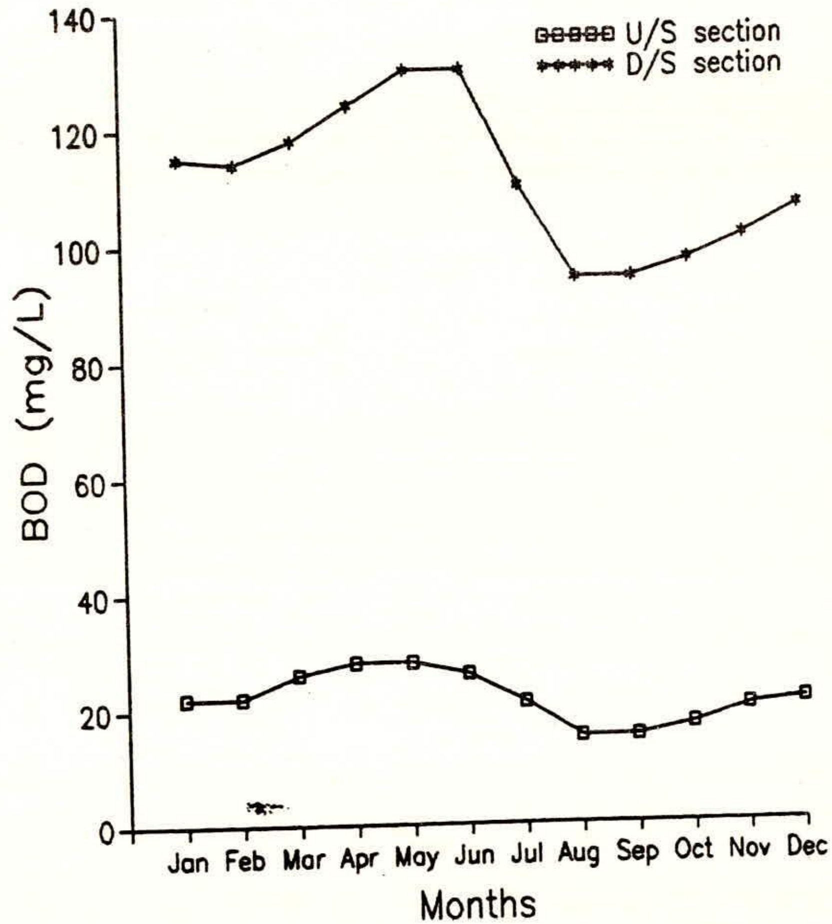

Fig. 11 Monthly variation of BOD at U/S and D/S section in river Kali

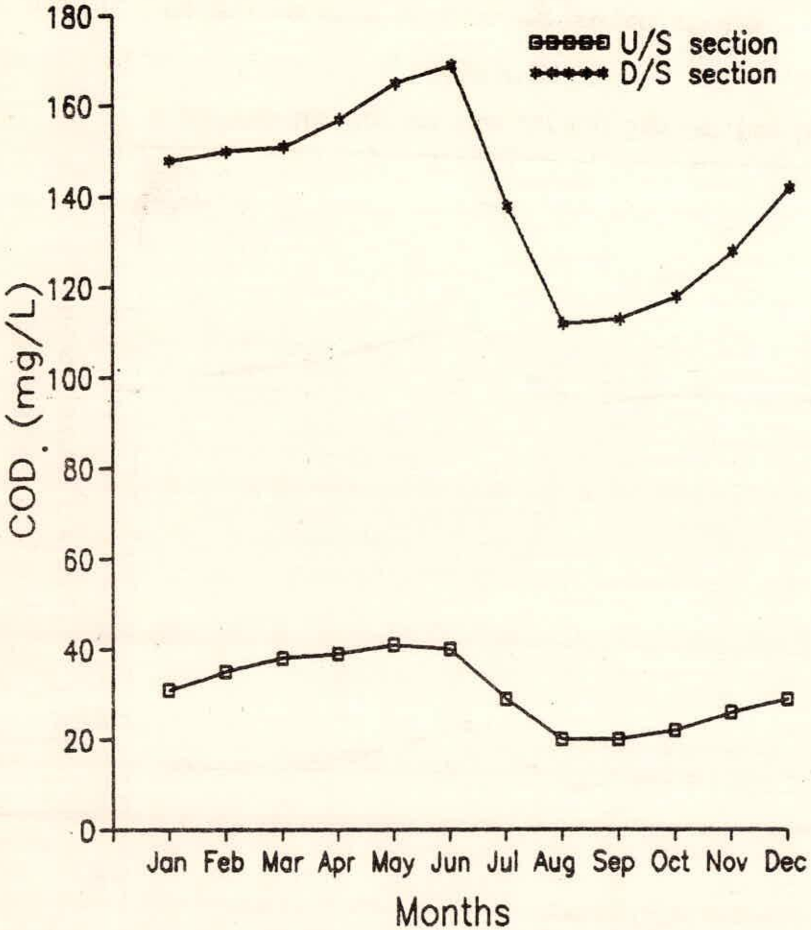

Fig. 12 Monthly variation of COD at U/S and D/S sections in river Kali.

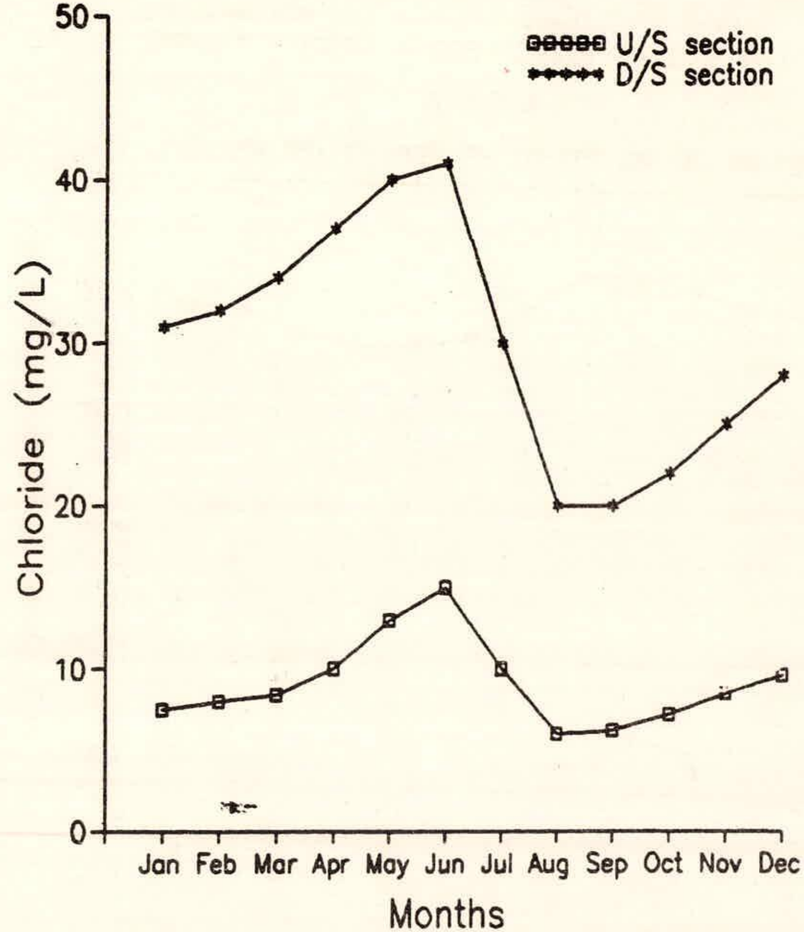

Fig. 13 Monthly variation of chloride at U/S and D/S section in river Kali

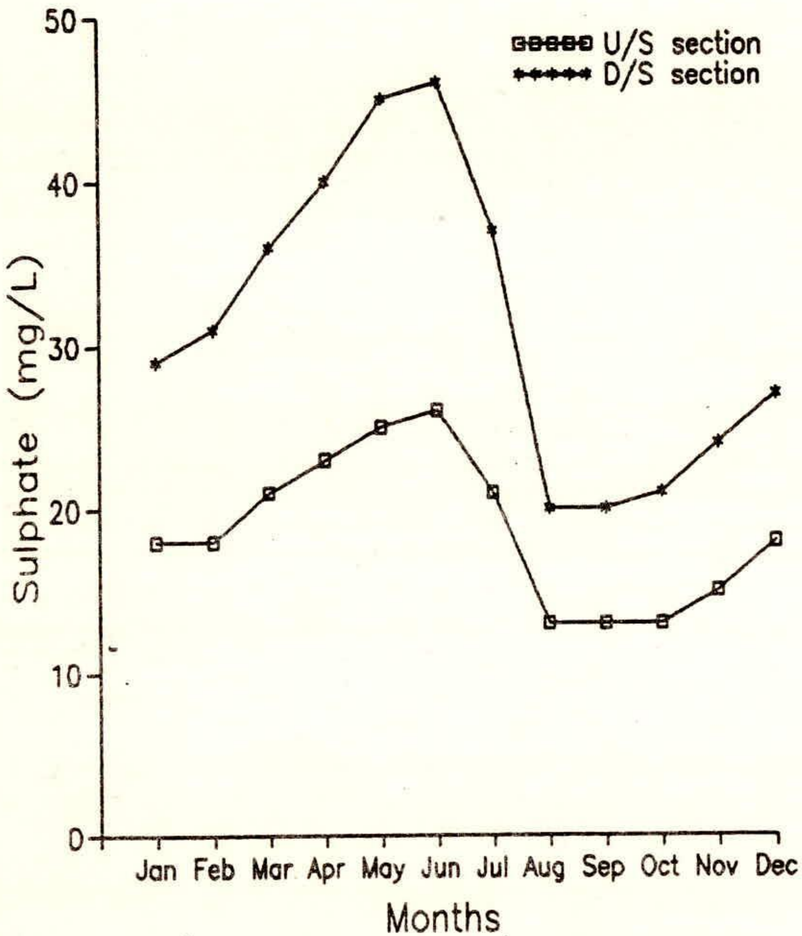

Fig. 14 Monthly variation of sulphate at U/S and D/S sections in river Kali

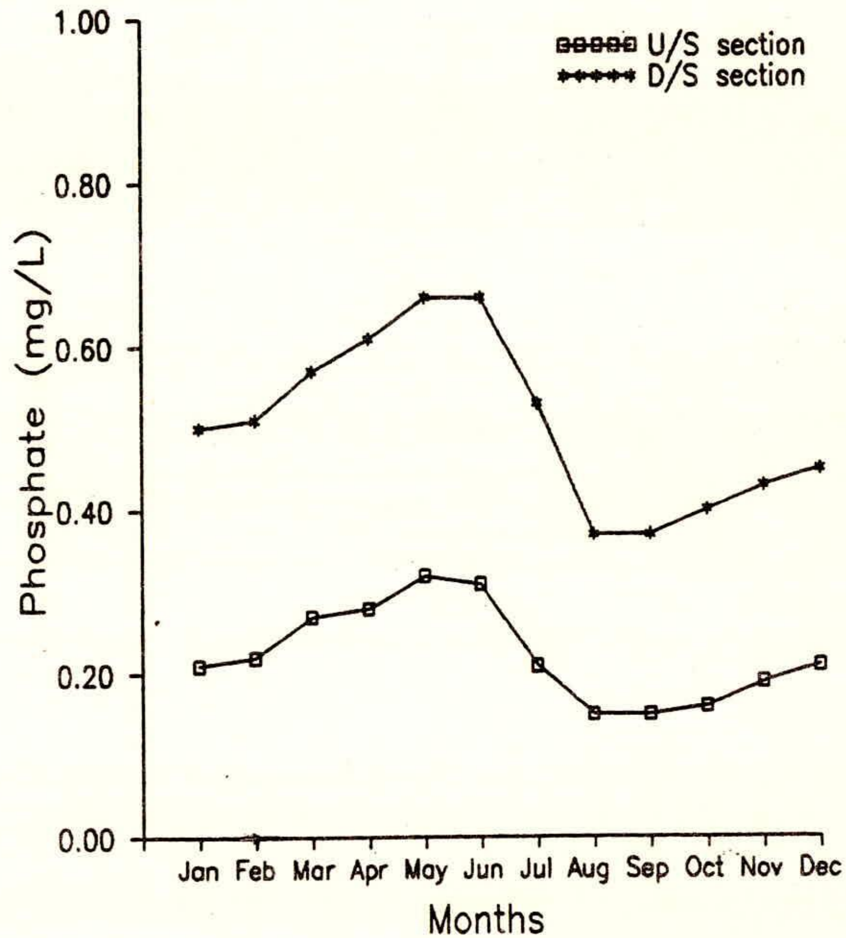

Fig. 15 Monthly variation of phosphate at U/S and D/S sections in river Kali

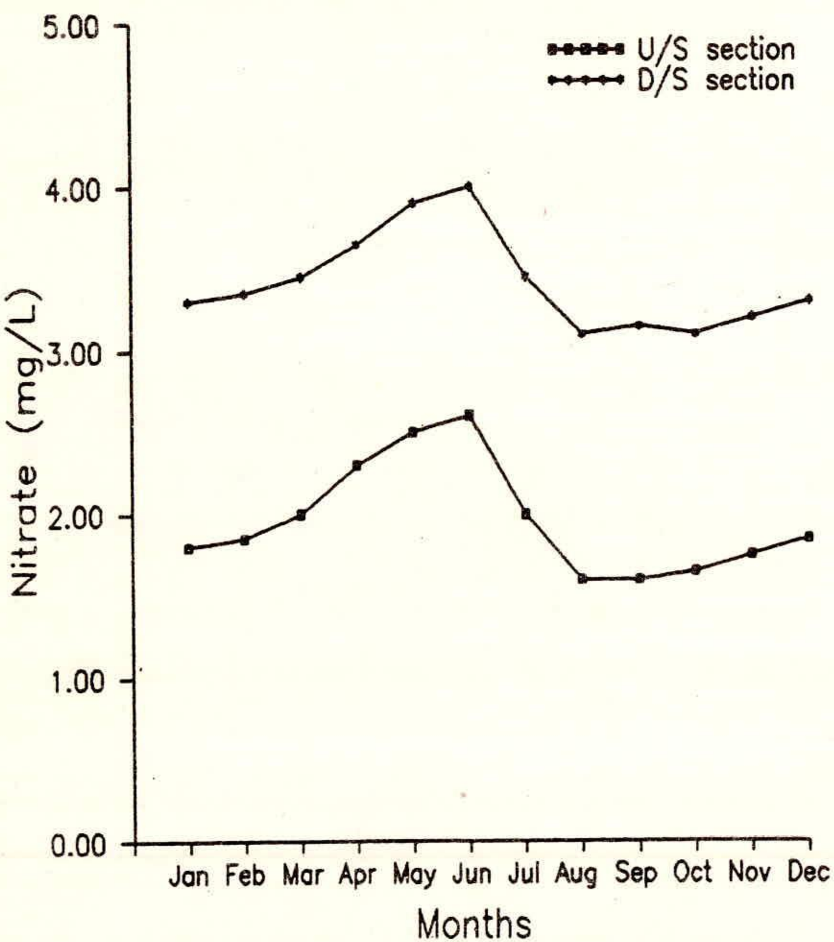

Fig. 16 Monthly variation of nitrate at U/S and D/S sections in river Kali

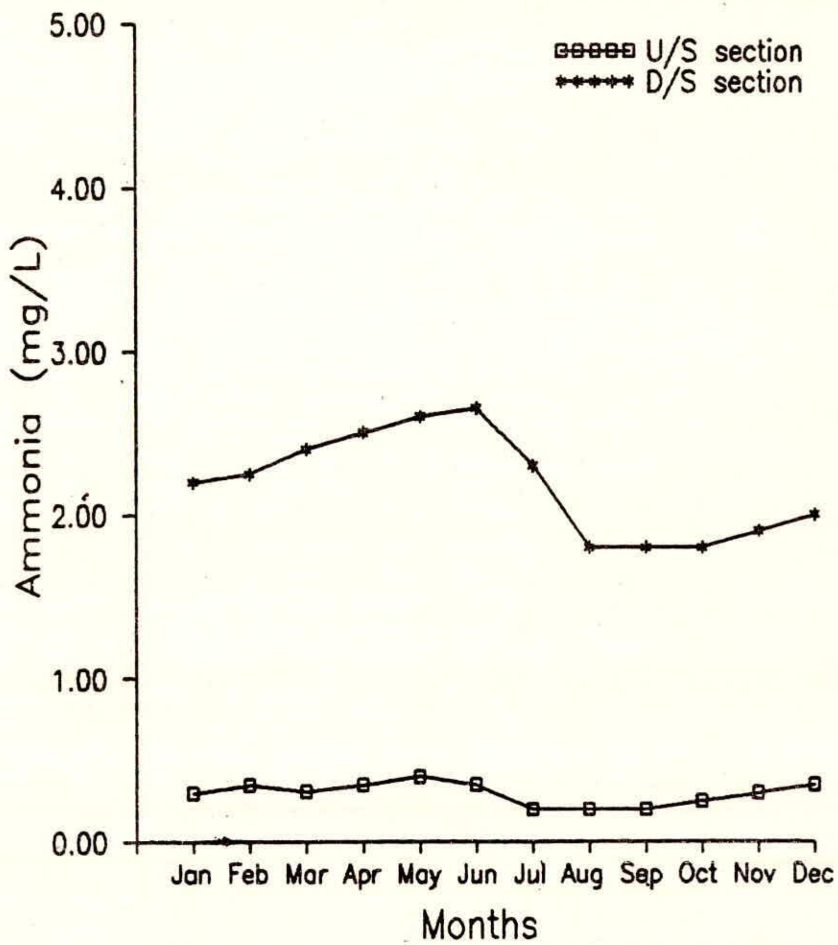

Fig. 17 Monthly variation of ammonia at U/S and D/S sections in river Kali

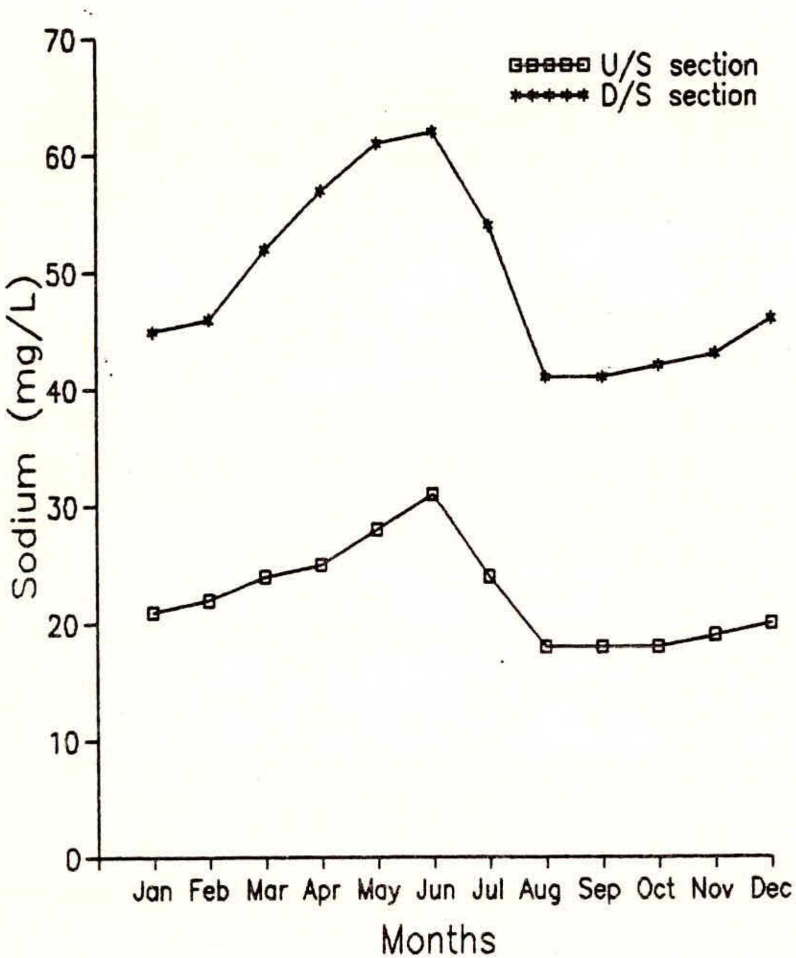

Fig. 18 Monthly variation of sodium at U/S and D/S section in river Kali

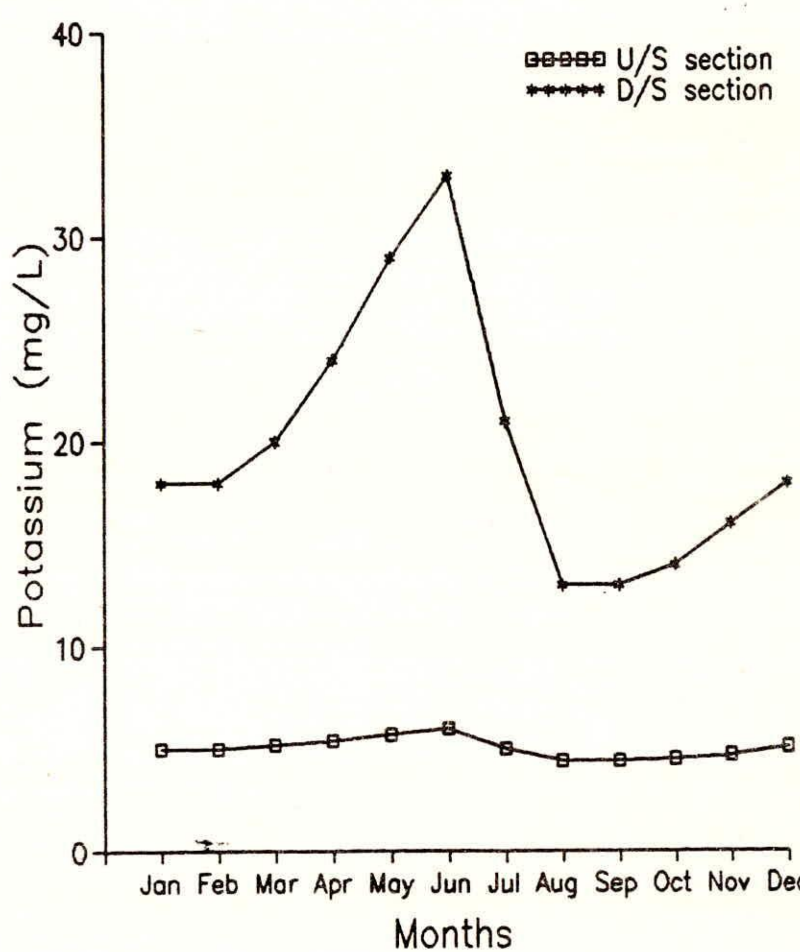

Fig. 19 Monthly variation of potassium at U/S and D/S section in river Kali

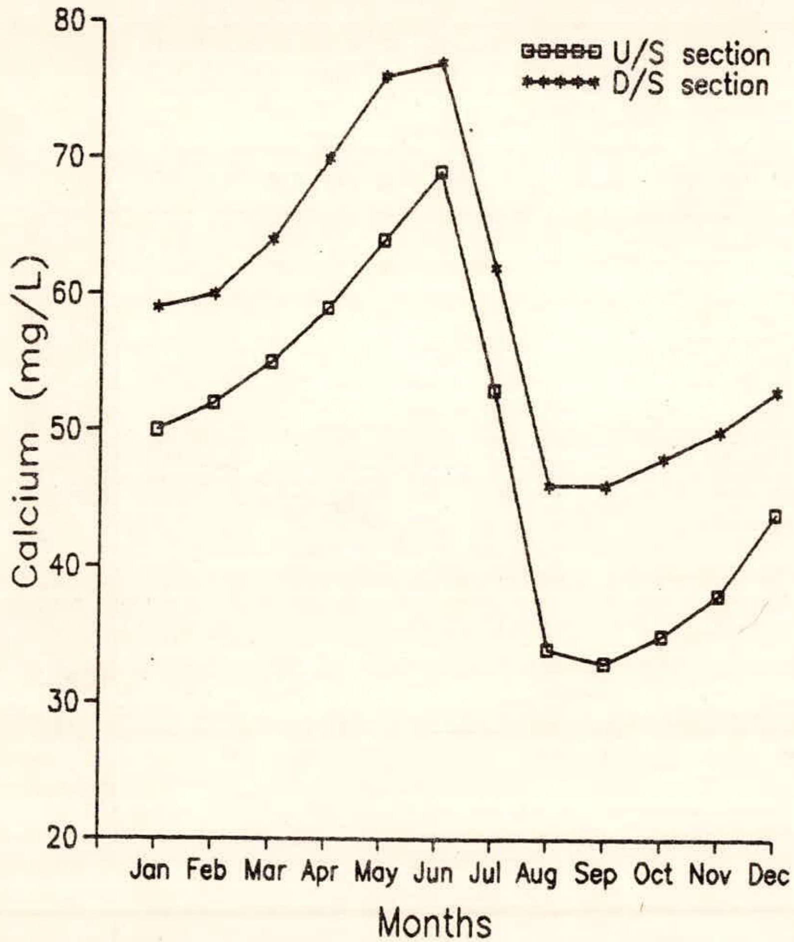

Fig. 20 Monthly variation of calcium U/S and D/S sections in river Kali

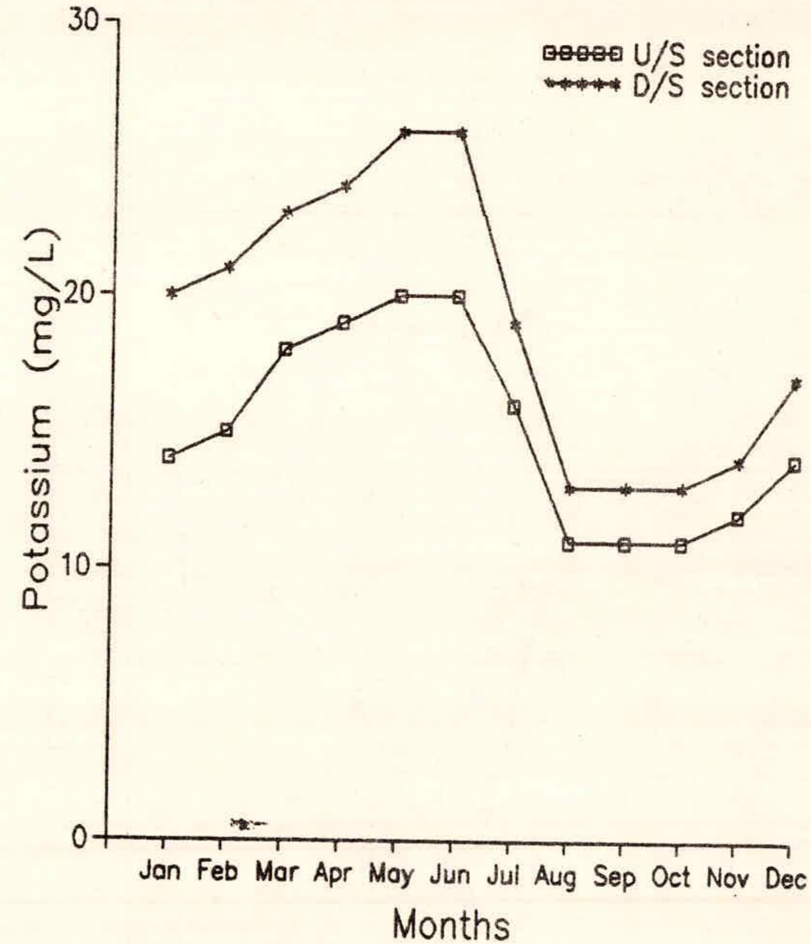

Fig. 21 Monthly variation of magnesium at U/S and D/S sections in river Kali

5.0 CONCLUSIONS

From the study conducted on river Kali, it is concluded that the river is subjected to varying degree of pollution due to numerous outfalls of untreated municipal and industrial wastes. The discharge of municipal and industrial wastes into the river at regular intervals do not allow any self purification to occur. The high values of BOD and COD are of main concern and the sources of such pollution need urgent control. Therefore, as a measure of conserving the aquatic life, it is suggested that before discharging the wastes into the river, these should be treated either chemically or biologically to an adequate extent.

The data presented in the report shows conclusively that there are considerable variations in the concentration of various constituents with time. The report also gave an account of the advantages of using upstream/downstream river water quality data to estimate the load to the river and detect changes in the water quality characteristics within the river.

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