METAL POLLUTION IN JAMUNA RIVER AROUND DELHI

Dissertation submitted to the Jawaharlal Nehru University
in partial fulfilment for the Degree of
MASTER OF PHILOSOPHY

(REKHA L.) SITASAWAD

(SCHOOL OF ENVIRONMENTAL SCIENCES , *Dissertation, 1980*

JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI-110067

1980

With love to

     my parents
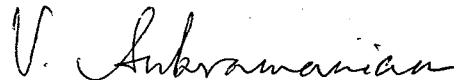
        and

           Prof. Jayakumar Magar

<u>C e r t i f i c a t e</u>

This is to certify that this dissertation entitled "Metal Pollution in Jamuna river around Delhi", is a bonafide work of Miss Rekha L. Sitasawad, carried out at the School of Environmental Sciences, Jawaharlal Nehru University, New Delhi.

This work has not been submitted in part or full for any other degree or diploma of any other University.

Dr. V. Subramanian
Supervisor

Prof. J.M. Dave
Dean

Date: 10·1·80

School of Environmental Sciences
Jawaharlal Nehru University
New Delhi 110 067.

A̲c̲k̲n̲o̲w̲l̲e̲d̲g̲e̲m̲e̲n̲t̲s̲

(Rekha L. Sitasawad)

A b s t r a c t

59 Samples have been collected from River Jamuna around Delhi and analyzed, which show the time, space and seasonal variation in the concentration of metals present, with the possible sources, responsible for the water quality of river Jamuna.

Particularly in Delhi territory, total waste discharge from seventeen different drains, is the major pollutional load. To make an accurate analysis, drain water also was analyzed for different drains and total waste discharge of drains regarding metal concentration have been calculated in MT/yr, which is obviously higher than river water.

Further, this data is compared with the natural sources, at upstream of Wazirabad where river Jamuna enters Delhi region and at Okhala to check the pollution load due to waste addition in between.

With this study it is concluded that the metal concen- tration observed at Okhala is higher than that of Wazirabad in case of Mn, Cu, Zn and Pb, while Cr, Fe concentration is same except Ni.

But from overall impact of drain discharges, on river water quality, it is observed that metal concentration at Okhala is not much higher as compared to the total waste discharges. It simply reflects that metals are very much depositing in the bottom sediments of river Jamuna, though Cr, Fe, Ni and Pb are exceeding the standard limits.

C o n t e n t s

CHAPTER - I

Introduction

Trace metals in natural waters have become a significant topic of concern for scientists and engineers in various fields associated with water quality as well as concern of the general public. Direct toxicity of man and aquatic life and indirect toxicity through accumulations of metals in the aquatic system are the focus of this concern.

Surface waters are usually very dilute solutions containing cations, anions and neutral species. Aquatic metal chemistry is important because water as a source is necessary for man and a substance is abundant. We are concerned with quality of water.

A complex human health hazard that can be related to the organic and inorganic substances dumped into the water in mammoth quantities by our fast changing civilization. Some of these substances, among them a variety of chemicals and metals, pose a direct threat to human health of uncertain dimensions.

Several inorganic components of waste waters and natural waters are in establishing and controlling the water quality. The concentration of inorganic substances in water are increased both by geologic formation with which the water comes in contact

and by the waste water, partially treated or untreated, that are discharged to it.

Compounds of the metals are wide spread in the environment as minerals, many of them in soils, lakes, rivers, streams, estuaries and oceans etc. These compounds occur as a result of man's activity or natural processes.

The activity of metals in aqueous system vary depending upon the metal species which are formed. Metals in low concentrations in natural waters are essential ingredients for living organisms, but their soluble derivatives can be toxic to high levels. Toxic metals in the environment is a more insidious problem than any other pollution. Because of their known toxicity international standards have been set for metals found in public water supplies. The standards set up by WHO, USPHS and India are given in the Appendix - Table 22.

A group of metallic species which includes Ca^{++} and Mg^{++} causes water to be hard, Iron and Manganese tend to cause high turbidity in water and cause stains. The cations of metals such as Cu, Ni, Zn, Pb, Cr are highly poisonous to humans and animals alike.

Taking into consideration of the importance of the metal toxicity in the natural aqueous system, the study on the role of metals in the river water is essential.

In India, most of the industries are inorganic oriented. Due to fast growing industries and dense population, river pollution in India is increasing. (C.A. Sastry et. al. (1972) as a result of improper disposal of untreated as well as sullage waste water. It has long been known that polluted water resources were among the most dangerous of disease carriers.

Most of the cities of metropolitan groups are located upon rivers or lakes that may be utilized as a source of domestic and industrial water. These cities draw their water supply from river and return the sewage partially treated or untreated into the river.

Cities like Calcutta, Delhi, Allahabad etc., rely on river water for their needs. Delhi, the Capital of India, is located on the river bank of Jamuna, one of the important tributary of river Ganga in Northern India. Within the Union Territory of Delhi, the spread of the river Jamuna is 48 kms. The water supply of the city is mainly drawn from this river at Wazirabad and Okhala. The total waste water in Delhi is 9,60,000 KLD (CWPCB Report, 1979), out of which only 46.4% is treated and the rest untreated 51,000 KLD waste water finds its way into the river Jamuna directly through seventeen drains. The river Jamuna supplies 27,000 KLD (CWPCB Report, 1979) of drinking

water daily at least to 3,00,000 people.

Since concentration of various inorganic constituents can greatly affect the beneficial uses made of the waters, it is well to examine the concentration of metals particularly those added to surface waters via waste discharge.

The work on the metal pollution in Jamuna river around Delhi provides the periodic variation in concentration of metals and the interrelation between the existence of metals which are responsible for the water quality in Delhi region. The discripencies in these values are useful for further investigation of the areas which are not well understood.

Review of previous work

Following the disaster in Minimata Bay, Japan
(Irukayma et. al., 1961), the efforts leading to the under-
standing of the cycling of certain contaminating métals in
aqueous and biological system. Such studies have tended to
centre on the metals which are known for their toxicity.

The study by Durum et. al. (1962) provides some obser-
vations on the implications of the minor element content of some
major streams of the world. Of 15 or more minor elements of the
world's principal river waters range much over 100 ppb levels.
For example, Atlantic coastal river water in the aggregate are
slightly more enriched in concentration of Silver, Chromium,
Manganese, Molybdenum, Nickel, Strantium and Titanium. Median
values of ratios Ba/Sr, Ni/Cr and Ni/Cu are reasonably consistent
in principal drainage from North America, but the ratio tends to
be slightly greater in global northern latitudes than in southern.

In relative study of physico-chemical characters in river
water system in Amazon river has been studied by Gibbs (1967,
1970) and he claimed that geological terrain, vegetation, tempe-
rature, climate, addition of tributaries are primary factors
while city waste, industrial waste and other man-made activities
are secondary factors affecting the chemical nature of river water.

Turekian et. al. (1967) has studied the concentration of Cr, Ag, Mo, Co and Mn in suspended material in streams. The sediments of the Mississippi and the rivers west of draining into the Gulf of Mexico as well as the Rhone river resemble average shale in composition, while the rivers of the United States east of the Mississippi are considerably higher in concentration. This difference is not due to differences in cation exchange capacity but rather perhaps to a greater amount of a trace element rich soil component and industrial contamination in the eastern rivers. The Susquehanna river alone is supplying about 45 tons of Ag a year as possibly recoverable detrital material. Loring (1968) has noticed that Fjord sediments are enriched in Zn and Pb when compared to sediments from St. Lawrence estuary and the open gulf of St. Lawrence (Bewers et. al., 1974). Spencer et.al. (1968) published the factors affecting element distribution in sediments of Sorfjord, Norway.

The work reported by Fonselium (1970) for the Mediteranean, the Red Sea and the Arabian Sea is similar to work done by Durum et. al. (1962).

Preliminary results from a study of the chemical composition of Southern lake Michigan sediments published by Shimp (1970) indicate that Pb, Zn, Ni and Cr accumulate in the upper few centimeters. Of these lake deposits, at this intervals concentration

of these elements appear to be related to the total organic carbon in the sediments. Major constituents determined were Ca, Mg, K, Na, Ti, Mn and Phosphorous found in smaller amount. Trace elements determined were Zn, Ni, Cu, Co, Cd, Cr and Pb.

On the basis of analytical results of seasonal cycle sampling, the water chemistry data of the Amazon river are presented by Gibbs (1972). Based on these type of analysis, hydro-geochemistry of surface waters of the Mackenzie river drainage basin, Canada, were investigated by Reeder et. al. (1972) and the factors controlling inorganic composition were studied and it has been observed that Mackenzie river is virtually unpolluted. Twenty two minor and major inorganic chemical components are reported together with the physical properties and documented details of the area and proportion of rock types in the sub-basins.

Collinson (1972) modified the work with Shimp (1970) in bottom sediments from Peoria lake, middle Illinois river. The results showed that upper Peoria lake bottom sediments contain more Lead, Zinc, and Chromium than previously studied lake Michigan. In this study, turbidity appears to have an inverse relation to trace element concentration.

Skei et. al. (1972) observed that the distribution of heavy metals in sediments of Sorfjord Norway, whereas Oliver (1973) has

shown the heavy metal levels in Ottawa and Rideau river sediments which were analysed for Hg, Pb, Cu, Zn, Ni, Co, Fe, Mn and Cr using Atomic Absorption Spectrophotometer. He found that some anomalously high heavy metal concentrations in the sediments in certain locations appeared to be related to pollution of the rivers by municipal and industrial waste water discharges and waste disposal practices.

Distribution of trace metals in the pore waters of shallow marine sediments by Duchart et. al. (1973). In this study it has been pointed out that the distribution of dissolved Mn which is regular downward decrease in all cores. Cu, Ni, Zn, Co and Pb also show variable concentration profiles which depend on different physico-chemical environments generated by variable amounts of contained organic material and different accumulation rates, while Loring (1973) presented the morphology and sediments of the gulf of St. Lawrence river.

The variations of dissolved constituents with discharge in some Norfolk rivers have been noted down by Edwards (1973), as the rivers were supersaturated with Calcium carbonate when compared with the solubility product of calcite and showed no signs of equilibrating, and the work put forward by Gibbs (1973) on mechanisms of trace metal transport in rivers shows that the trace metals

transported by the Amazon and Yukan river were analytically partitioned among the transport phases in solutions, ionic exchange, organic materials, metallic coatings and crystalline solids.

Further the study of St. Lawrence river carried out by Subramanian (1974) showed that the resulted data on river water chemistry has been compared with other major rivers of the world. Besides, it has been claimed that the total dissolved load carried by the river into Atlantic may be significant mass transfer and budget studies. The major ionic composition is same throughout the fresh water region. Potential transformations of Chromium in natural waters have been reported by David et. al. (1974) and it has been found that the Cr III and Cr VI are readily interconvertible under natural conditions and the results of this study indicate that Cr VI is reduced by Fe II, dissolved sulphides and certain organic compounds with sufhydryl group while Cr III is oxidized by MnO_2 and at a slow rate by O_2 under conditions approximating these in natural waters. Loring et. al. (1975) presented Mercury concentration in the gulf of St. Lawrence whereas aspects of trace metal contamination in the coastal rivers of Israel were studied by Kronfeld et. al. (1975). Nine elements of biological concern, Cr, Co, Cu, Cd, Ni, Pb, Hg, Zn and Ag were investigated in the sediments of the most important coastal streams in Israel. All of these are

subjected to degree of domestic and or industrial sewage
input with the consequent liability of contamination by trace
metals.

The Ayyalon, Gadura, Quishon and locally the Hadera rivers
contain sediments exhibiting severe pollution effects. There
is a danger of infiltration through the soils into the ground
waters as well as exposing near shore fauna to sediments conta-
minated by possibly toxic trace metals. The other rivers bear
smaller levels of trace metals, however, an increase of the Pb
and Zn levels occurs near major highways.

Whereas field observations on the transport of heavy
metals in sediments were observed by Groot (1975). Under temperate
climatic conditions the sediments on their way to the sea can
undergo changes in their metal composition by mobilization of
these elements as soluble metal-organic complexes. In addition,
dependent on the velocity of the river currents, different types
of suspended matter are transported and sediments transported
by some large rivers carry large amounts of these elements result-
ing from pollution.

Lee (1975) studied the role of hydrous metal oxides in
the transport of heavy metals in the environment and it has been
found that uptake and release heavy metals is influenced by the

pH of the solution and by the presence of organic and inorganic complexes. Further it is noted that one should not judge the potential role of heavy metals in influencing the aqueous environmental chemistry of Cu, Zn, Ni, Cd etc. based on the concentration of Fe and Mn in solution. In the study of metabolic cycles for toxic elements in the environment, Wood (1975) studied the kinetics and mechanisms of various elements and shown that small perturbations of these cycles can change the equilibria involved to change the concentrations of toxic intermediates.

Further investigations of heavy metals and other persistent chemicals, western part bay Australia were carried out by Shapiro (1975) in which he concluded that in certain estuaries in Australia, such as Derwent and Tamar in Tasmania, evidence of abnormally high concentration of Zn, Cu and Cd were found in oysters growing in these bodies of water. The variations in trace elemental concentration along the length of Ottawa river have been verified by Merrit (1975) in which abnormal fraction of most elements between water and suspended material was observed in a section of the river where large quantities of fresh wood fibres were being produced by fluming operations.

While the analytical techniques for heavy metals (Herbert, 1975; Henrikson, 1977), physical chemical methods of heavy metal removal (Patterson, 1975) and effects and removal of heavy metals

in biological treatment (Adams et. al., 1975) have been grouped in the study of heavy metals in the aquatic environment by Krenkel (1975).

In (1976), Loring reported the distribution and partition of Co, Ni, Cr and V in sediments of Sorfjord Saguenary. In this study, he showed that the discharge of industrial input has not resulted in an increase in the concentration of metals above their natural levels in the sediments.

Loring (1976) again examined the distribution and partition of Zn, Cu, and Pb in the sediments of Sorfjord Saguenay and it was observed that the concentration of the element increases with decreasing grain size.

Heavy metals in the deltaic sediments of the Fraser river, British Columbia have been reported by Grieve (1976). Detailed studies of the distribution of labile and non-labile trace metals indicate that the increased concentration of trace metals is associated with both the detrital minerals and hydrous Fe-Mn oxides. Finally high concentration is observed on the tidal flats influenced by discharge of metal rich sewage.

The analysis have been performed on the major rivers Amazon, Congo, Ganges, Orinoco and Parana by Martin et. al. (1976). These analysis include some of the major metal concentrations and elemental rates of dissolved and suspended transport by

rivers. It also shows the relationship between dissolved
and solid transport of Ca, Mg, and K.

Yeats et. al. (1976) put forward the study on trace metals
in waters of the Saguenay Fjord. The significant enrichment of
Fe, Zn, Cu, Ni, Co, Cd and Zn in the surface water relative to
the intermediate depth water, reflects run-off inputs. While
Subramanian (1976) has also shown that pH is also a major factor
for the control of chemical composition of river water.

The actual study on environmental pollution by heavy
metals carried out by Cook (1977) gives the information about
non-radioactive metals and their effect on the environment with
the health hazards involved. Distribution of inorganic components
in water has been identified by Glass (1977). Although the metal
aquo ion is thought to be the reactive form for biologic inter-
actions, the fraction of the total metal present in this form
may be small and highly variable depending on the available
complexing agents or ligands and the magnitude of the interactions.

Calculations of the inorganic components in lake show
the distribution of metals and ligands in water to be complex and
indicate that analytic measurement must be sensitive in the range
10^{-8} to 10^{-12} M for most metals and the analysis of drinking
water from Duluth on a continuous basis and at different locations
shows large fluctuations caused by variety of factors.

A recently proposed trace metal speciation scheme was applied to the determination of chemical forms of Cu, Cd, Pb and Zn in four natural fresh waters and a tap water. With this Florence (1977) added some reliability of the technique and the effect of various methods of storage on the speciation results. Similar study by Bruegmann (1977) contributes a scheme of the many forms of the occurrence of trace metals in the waters, whose concentration amounts to less than 0.1 ppm. Further sample preparation and detection techniques are described.

Analysis of the concentration of heavy metals in the Derwent estuary was done by Bloom (1977) in filtered waters, suspended particulates, sediments, shellfish, fish, airbore particulates and sewage have confirmed work of other investigators showing that Derwent estuary is highly polluted particularly with Hg, Cd, Pb and Zn and have added further information regarding the distribution of each metal.

Blutstein et. al. (1978) supports the work regarding distribution of species of Cu, Pb, Zn and Cd in Yerra river estuary.

Modes of metals transport above and below waste discharge on Haw river was observed by Shuman et al. (1978). Modes of Cr, Sb, Fe and Co transport were examined for difference between control and polluted stations within the selected small drainage

area of the Haw river, North Carolina. Difference appeared among a greater number of transport modes for Cr and Sb elements suspected of, being added to the river as industrial wastes than for Fe and Co with no known industrial input.

Heavy metals in the bottom mud at the mouth of 91 rivers in Japan were analysed and the data were published by Todo et. al. (1978). Samples of the mud were collected from the upper stream near the mountain, not polluted with waste water. It was concluded from these data that the concentration of the heavy metals among 193 mud samples up the river dispersed in a narrow limited range, compared with that of the river mouth.

As part of regional surveys of lakes in Norway, the concentration of Zn, Pb, Cu and Cd were measured in surface and bottom water samples collected from representative, small pristine lakes in October 1974 to 1977 by Henrikson et. al. (1978) and it is found that increased heavy metal concentration in acid lake may also be due to increased mobilization of metals due to acidification of soil and surface waters.

Trace inorganics in rural ptable water and their correlation to possible sources have been pointed out by Sandhu et. al. (1978). Ninety eight water samples comprising about 10% of the total sources available to rural homes in Hampton County, South Carolina were randomly collected and analysed for inorganic constituents. From

this study it has been concluded that chemical contamination is widespread in this area. A number of water samples showed unacceptable levels of As, Fe, Mn, Hg and colloidal materials were chiefly responsible for turbidity in 19% of the water sources. Acceptable levels of Cd, Cu, Cl, Pb, NO_3, PO_4, Na, K, total solids and Zn were determined in most of the samples. Fe, Pb and Mn appear to have come from corrosion of antiquated plumbing inorder homes. Grebenovsky et. al. (1978) elaborated methods of stripping voltametry for the determination of Cu, Pb, Cd and Zn on Hg film electrode and determination of Ag on the electrode from glassy carbon in drinking water. Cu, Cd, Pb and Ag are determined in the medium of dil. HCl and Zn in the medium of pyridinium chloride. This paper presents a comparison with common procedures of atomic absorption and photometry.

Nitrates and phosphates in the drinking water in the district Michalovce estimated by Birova et. al. (1978) deals with the observation of the effect of artificial fertilizer on the quality of drinking water. The concentration of Zn, Pb, Cu, Al and Mn were determined in sediment cores from windermere by Taylor (1979) N.W. England. Zn, Pb and Cu are greatly enriched in sediments deposited during the last Ca. 130 years. Maximum concentrations are 1180 ppm of Zn, 589 ppm of Pb and 140 ppm of Cu compared to baseline concentrations of 160, 56 and 24 ppm respectively. Known sedimentation rates have been used together

with the measured concentration to calculate fluxes of the three metals into the lake sediments. Metal sources and transport mechanisms have been discussed wherever possible. From this study it appears that atmospheric supply of the metals and uptake by diatoms may be important factors in controlling sediment concentration. While Jennett et. al. (1979) supported the Shuman's (1978) work. The investigation on metal transport from mining, smelting and milling water shades shows that run off transport is a major factor in moving metals from one ecosystem to another.

Similarly Cu-complexing capacity of natural river water, well water and artificially reconstituted water have been noted down by Cardy et. al. (1979).

In Indian contest, the work by Srivastav et. al. (1964) put forward the concept of self-purification of river water at Okhala water works and the observation by Kaushik et. al. (1964). gives the information about coliform periodicity of river Jamuna at Wazirabad.

The study by Balani et. al. (1965) provides some observations on the pollution of river Jamuna at Okhala Water Works. By this study it has been suggested that the water supplies be regularly monitored for content of free ammonia which may be useful in fixing the criteria of pollution of drinking water supply.

The survey of Najafgarh drain carried out by Balusu et. al. (1966) shows that the Jamuna river water pollution is mainly due to disposal of industrial waste water from Swatantra Bharat Mills, DCM Chemicals, Hindustan Insecticides etc. Geochemistry of the Ganga river water (Handa, 1972) shows that its water is of the alkaline earth bicarbonate type and the total dissolved mineral content is gradually increases with distance from source. During Monsoons the mineral content also varies but the bicarbonate ions are also more predominant. Ganga river carries around 90 million tons of various ions to the sea of which nearly 79 million tons are the alkaline earth bicarbonates.

Reports from CSMRS (1973) provides some chemical investigations of river waters in India which supports the same work done by GWPB (1972-76) for the rivers Jamuna, Chambal, Betawa, Ken and Ganga which shows the gradual increase of pollution in river Jamuna.

Agrawal (1977) predicted metal contents in the drinking water of Cambay. In this study analysis has been done for alkali metals as well as trace metals in which it is calculated that the Pb and Cd concentration is eight and four times greater than maximum allowable limits respectively.

The relative study of the raw water quality at
Wazirabad and Okhala has been studied by Kudra et. al. (1977).
From the seasonal variation in physicochemical and bacteriological
quality of water, it was observed that the pollution in the
river is increases progressively between Wazirabad and Okhala
due to discharge of industrial as well as domestic waste at
several points.

Recently the work done by Dalvi (1978) adds the knowledge
about the thermodynamic approach to the water mineral equilibria
in the Jamuna river basin, which favours the point that physical
weathering is greater than chemical weathering for mountaneous
rivers.

CWPCB (1979) Reports highlight some environmental problems
of Delhi which are mainly responsible for the increase in
pollution of Jamuna river water in Delhi region.

Biyani (1979) studied geochemistry of ground water in and
around Delhi for mineral water equilibria and control of lithology
on concentration of different ions. It has been observed that
concentration is less in monsoon samples and high in summer.
While Subramanian (1979) determined some observations in Delhi
ground water which include some metal concentration Ni, Cu, Zn,
Pb, Mn etc. from various regions of Delhi, and recently chemical
and suspended sediment characteristics of rivers of India have

been published by Subramanian (1979). Based on these investigations, the Indian rivers are alkaline in nature and 25% more concentrated in dissolved salts than the world's average. Discharge and downstream variations are also briefly explained and chemical, sediment and total load have been calculated for Indian rivers and erosion rates are compared to data for some major world rivers.

In fact the metal pollution as such has not been studied with respect to Indian river system though it has been studied on global scales. This is the first investigation worked out as Jamuna is an important river as well as major tributary of river Ganga.

CHAPTER - II

Geology & Nature of River Jamuna Around Delhi

River Jamuna rising at Jamnotri glacier of Himalaya in Terri Garwal district in U.P., at an elevation of 6330 m. Jamuna becomes a river after addition of the Rishi Ganga, the Uma, the Hanuman Ganga and other small streams. After flowing 275 kms. downwards it passes just touching Delhi (Rao, 1975).

River Jamuna is an equally important river as it is a major tributary of river Ganga. Jamuna river water is a mixer of different geology added by its tributaries. The major portion of the river Jamuna is occupied by recent alluvium (Fig. 1). The geological distribution of various rocks type around Delhi is recent alluvium. At its origin the river flows through the territory granites of the Simla Himalaya and lower Sivalik. Middle part is constituted of the lower Cuddaph system containing Delhi series (Wadia, 1970).

Following CWPCB Report, Delhi, the stretch of the river Jamuna within the Union Territory of Delhi is 48 kms. The water supply of Delhi city is mainly drawn from this river at Wazirabad and Okhala. The total waste water generated in Delhi is about 9,60,000 KLD. Only 46.4% of this total waste water is treated at Okhala coronation pillar and Keshopur waste water plants.

The rest of the untreated waste water finds its way into the seventeen open drains (Table 23) of the city. Amongst these seventeen drains, seven major drains are there which have been shown by asterick mark. Those drains are pouring the daily flow of untreated waste water about 5,15,000 KLD (CWPCB Report, 1979).

The contribution of these drains both in volume and in quantities of pollutants are significantly high. At Okhala Head Works, a canal parallel to river Jamuna flowing towards Agra, known as Agra Canal has taken off for irrigation and other purposes. The Kalkaji and Tughlakabad drains discharge directly into Agra Canal.

Description of Study Site

Sampling Stations:- Sampling stations were fixed according to the different mixing points of the different drains, connected to river Jamuna. The pattern of the collection of the water samples is:

   i) before mixing the drain into river so as to know the ionic concentration of river itself;

   ii) in the drain, to check the addition of the waste by drain before mixing;

   iii) at the mixing point of the drain, to see the dilution effect on the concentration of the ions;

iv) after mixing of the drain, to observe the

total concentration due to the specific drain

in the river.

The last sampling in Agra canal near Badarpur gives the effect of mixing of two more drains, Kalkaji and Tughlakabad which are directly connected to Agra Canal. Details of the study site have been shown in Fig. 1 and description is given in Table-A-1

Sampling Procedure:

Collection of water samples in river Jamuna and its major drains connected from Wazirabad to Agra Canal near Badarpur was done in the month of February, March, April and May, 1979. The collection of water samples is monthly and just below the surface of water in order to make an accurate and systematic assessment of the quality of river water, it's mineral content and periodic variation also.

Water samples have been collected in the drain, at the mixing point of drain, before mixing and after mixing the drain respectively in polyethelene bottles at various stations located. Though the seventeen drains are connected (Table 23) to river Jamuna, samplings have been done only for four drains (Fig. 1).

In the field itself, pH of the water was measured with a portable (Toshniwal) pH meter. Total alkalinity was also

measured to get the accuracy by titration with standard
HCl (0.01N) along with the temperature of the respective
samples in the field.

Laboratory Work:

After measuring conductivity with (Systronics[R]) direct
reading conductivity meter, all the water samples collected were
filtered through 0.45 um pore sized filter paper and part of the
each water sample was acidified with 2 ml of 0.1N HCl to prevent
the loss of metal concentration prior to analysis (Henrikson
et. al., 1977), and these samples put to see the metal ion con-
centration in ppm levels with (Carl Zeiss[R]) Atomic Absorption
Spectrophotometer. Rest of the unacidified part was kept for
Anion analysis whereas the suspended matter was calculated as
TSM in ppm.

i) Total Alkalinity: TA was estimated volumetrically by titration
with standard HCl using methyl orange as an indicator.

ii) Chlorides: Volumetrically estimated with standard (0.02N) AgNo$_3$
solution using K_2CrO_4 as an indicator

iii) Sulphates, Silicates and phosphates were estimated spectro-
metrically with (PMQ II Carl Zeiss) Spectrophotometer with
constant wavelengths.

iv) Acidified samples were used for the analysis of metal ion concen-
tration, as potassium sodium using emission and Calcium, Magnesium

Chromium, Manganese, Iron, Copper, Nickel, Zinc and Lead by absorption with (Carl Zeiss[R]) Atomic Absorption Spectrophotometer, using different standard solutions of metallic ions in ppm for the caliberation curve.

Though BOD and COD are important parameters, it could not be done because of the failure of electricity in those days. Examination of these parameters may shade additional light on the behaviour of the data. This presentation is made in the form of a graph which allows to persue the data for purpose of interpretation.

The graphical presentation shown in different figures (2 to 20) high-lights some of the very useful things: Thus it shows:-

1)   the actual variable concentration in the drain, at
     mixing point and in the river for each month;

2)   variations in variable concentration;

3)   seasonal variation in river Jamuna;

4)   space and time variation;

5)   amount of waste discharge at the mixing point from
     the particular drain; and

6)   variable concentration is plotted on Y axis with the
     stations on X axis. All the graphs presented, follow the

same pattern. Each explains

| Drain

Mixing
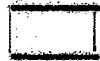
River

Along with this, it shows the different stations as

W = Wazirabad

C = Civil Mill

P = Power House

B = Barapullah

O = Okhala and Agra Canal.

River Jamuna Around Delhi

N
S

JAMUNA RIVER

Najafgarh Drain

•Wazirabad

•Boat Bridge
Civil Mill Drain
Power House Drain

Okhla

Recent Alluvium

Barapula Drain

Agra Canal

JAMUNA RIVER
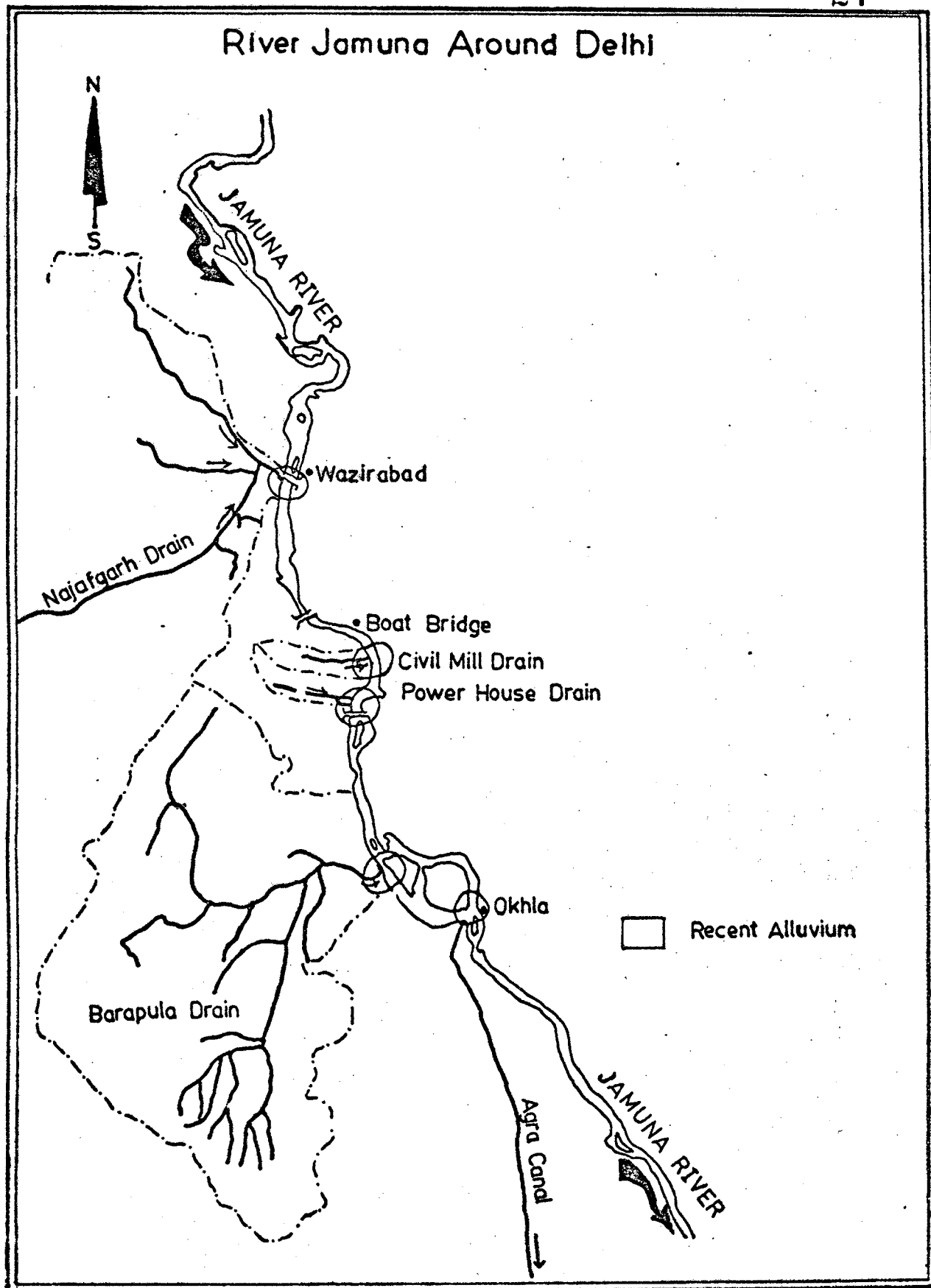
Fig. No. 1

Table - A-1

Stations	Sampling Spot	Sample Number	Date of collection	Nature of the sample	Description of the samples	Discharge from the drains Industrial, domestic & other in KL/D	
	Najafgarh	1		Drain	Drain water	18,100	270,00
Wazirabad	Drain mixing	2	24 Feb. 78	Mixing	River water		
	Wazirabad Barrage	3		B.M.	River water		
	Near Yamuna Bridge	4		A.M./B.M.	River water		
Civil Mill	Civil Mill drain near Shantivan	5		Drain	Drain water		5000
	Rahghat	6	28 Mar. 78	A.M./B.M.	River water		
	Old Power House drain	7		Drain	Drain water		5000
Old Power House	Drain mixing	8		Mixing	River water		
	Near I.P. Bridge	9	27 Apr. 78	A.M.	River water		
	Near Humayun's Tomb Bridge	10		B.M.	River water		
Barapullah	Barapullah drain	11		Drain	Drain water		125,000
	Drain Mixing	12		Mixing	River water		
	Friends Colony	13	24 May 78	A.M.	River water		
Okhala	Okhala	14		A.M.	River water		
	Agra Canal near Badarpur	15		Canal water	River water		

(This data is from CWPCB Report, 1979)   A.M.: After Mixing;
                                            B.M.: Before Mixing.

ANALYTICAL   DATA   IN   FIGURES
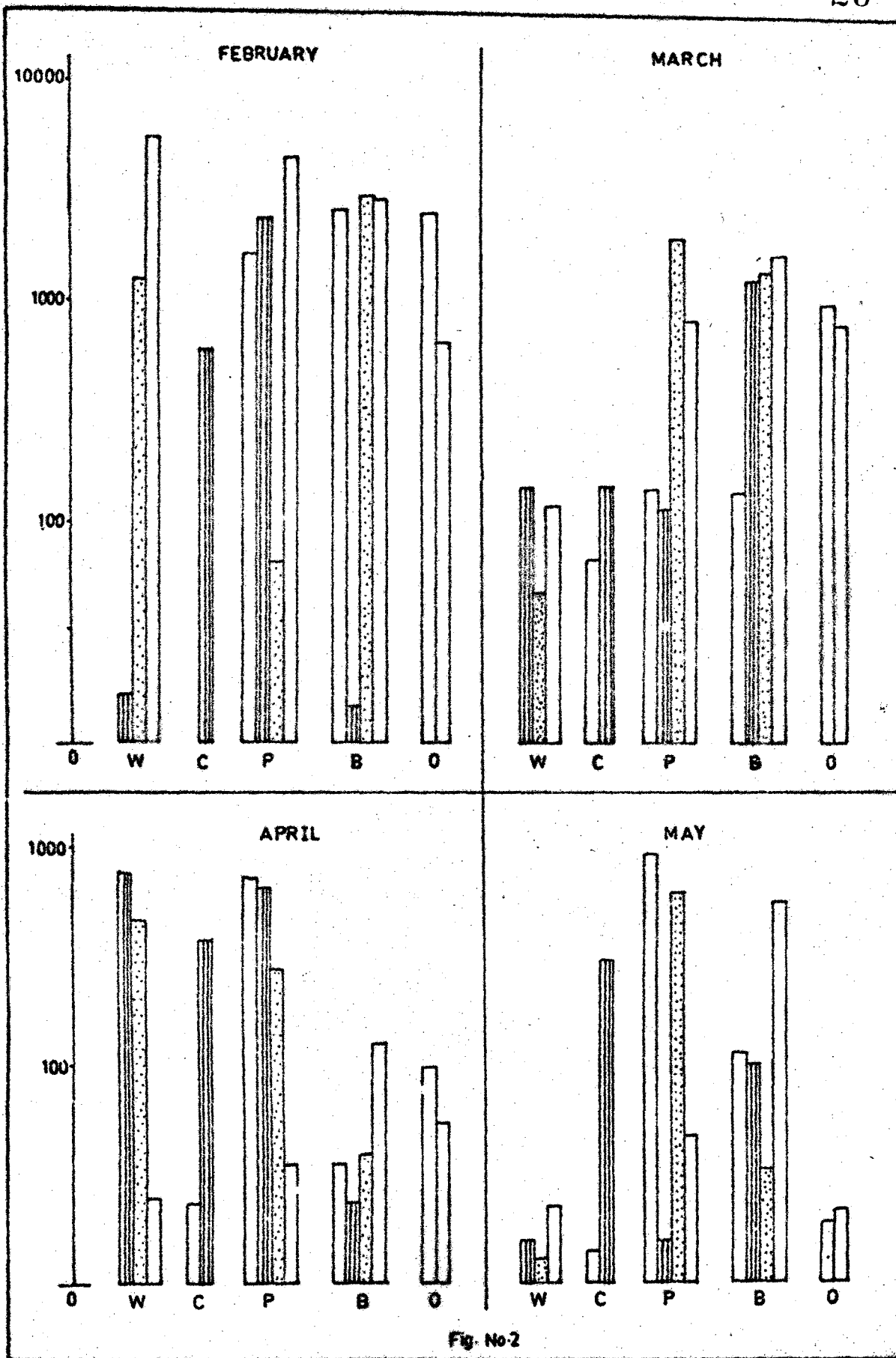
Fig. No.2

Conductivity in mmhos/cm

Fig. No. 3

31
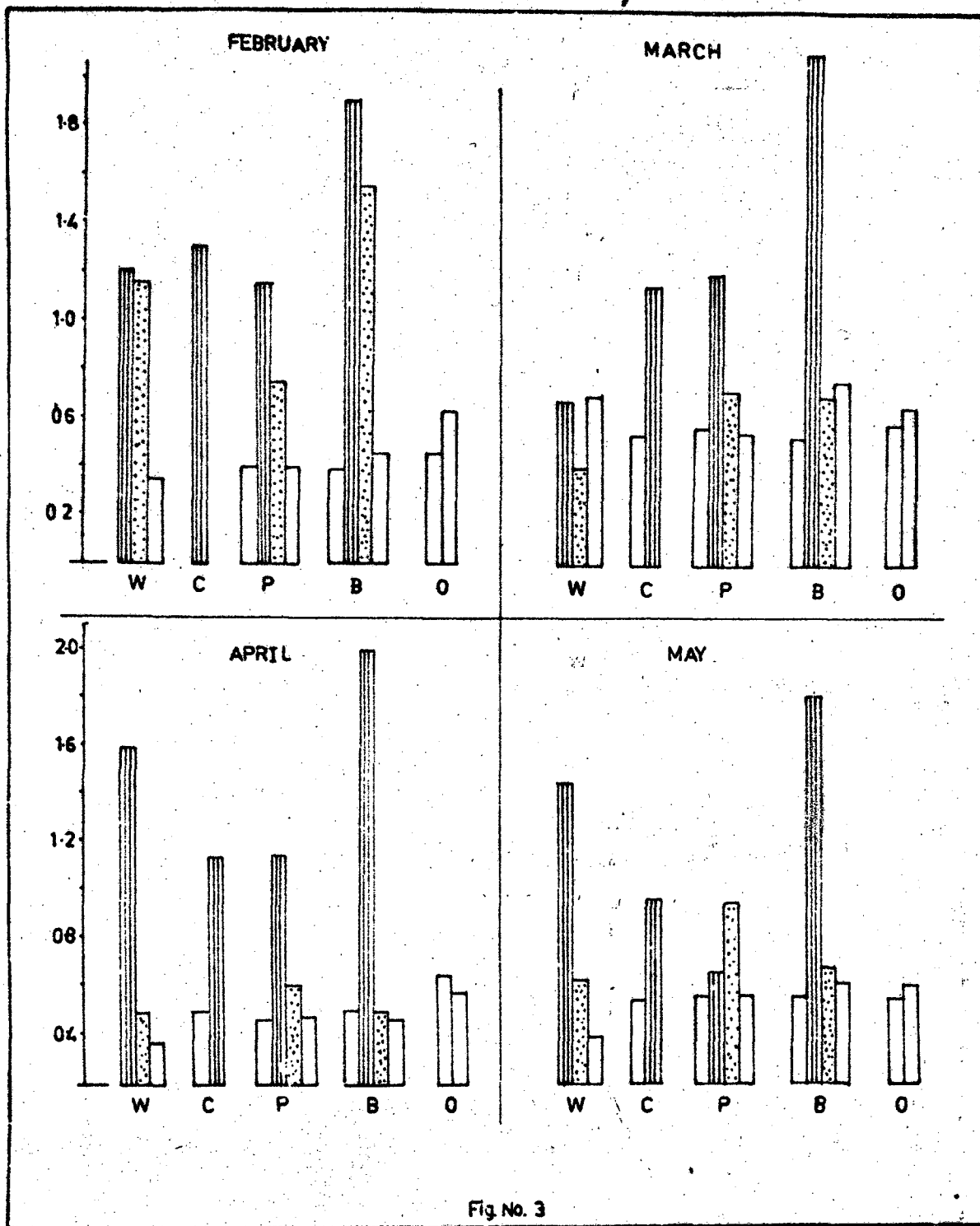
PH
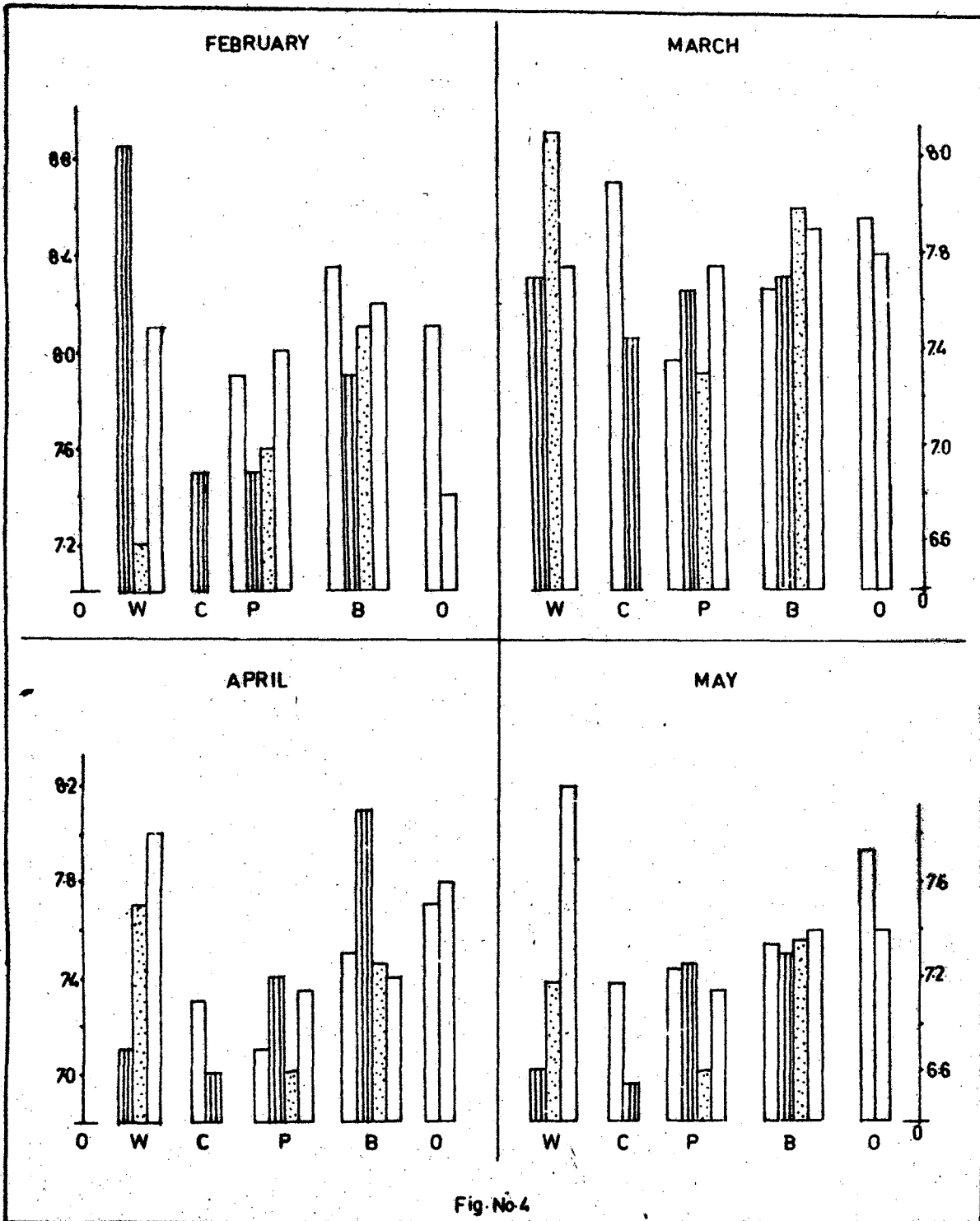
Fig. No. 4

Total Alkalinity in ppm
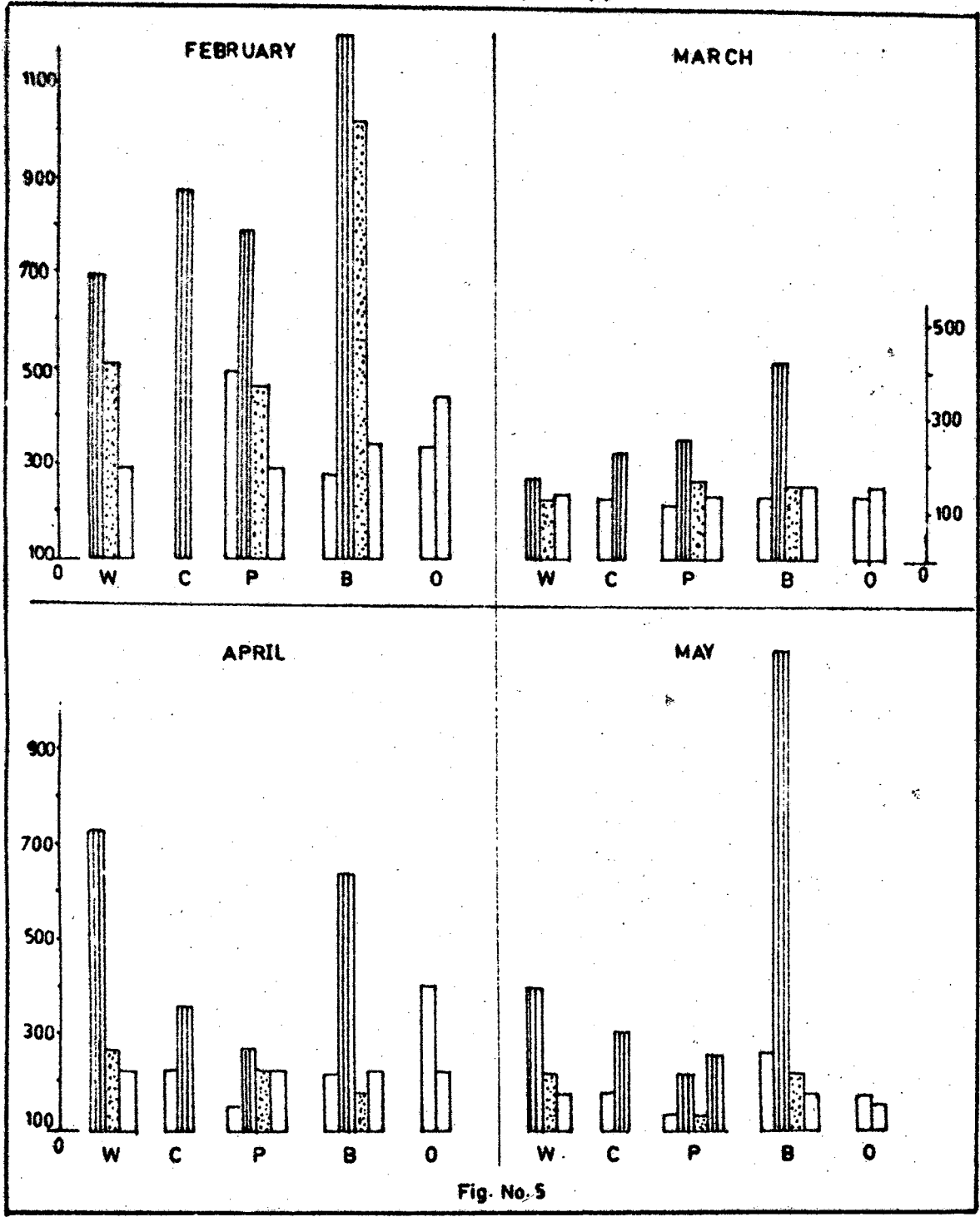
Fig. No. 5

Chloride Concentration in ppm
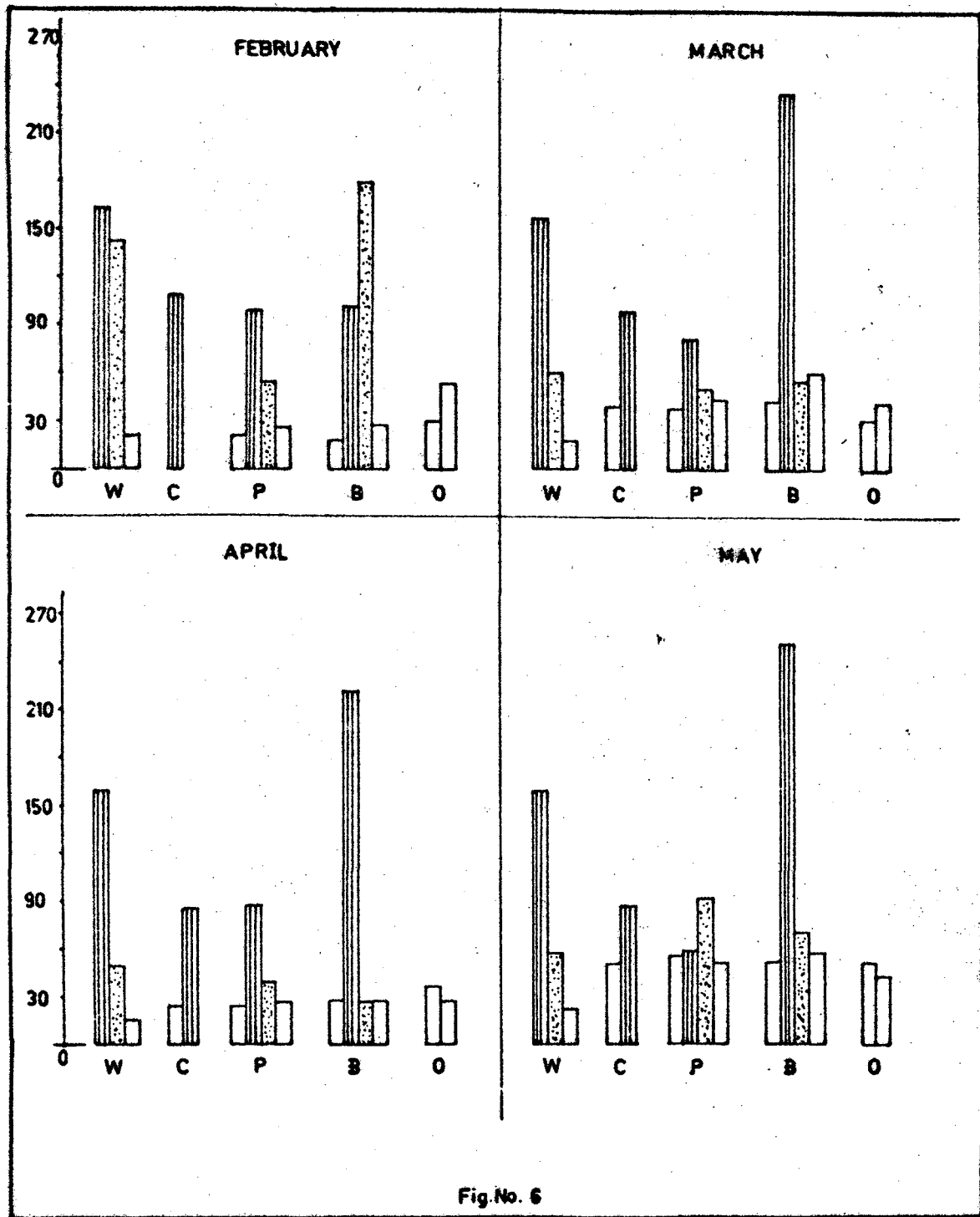
Fig. No. 6

Sulphate Concentration in ppm
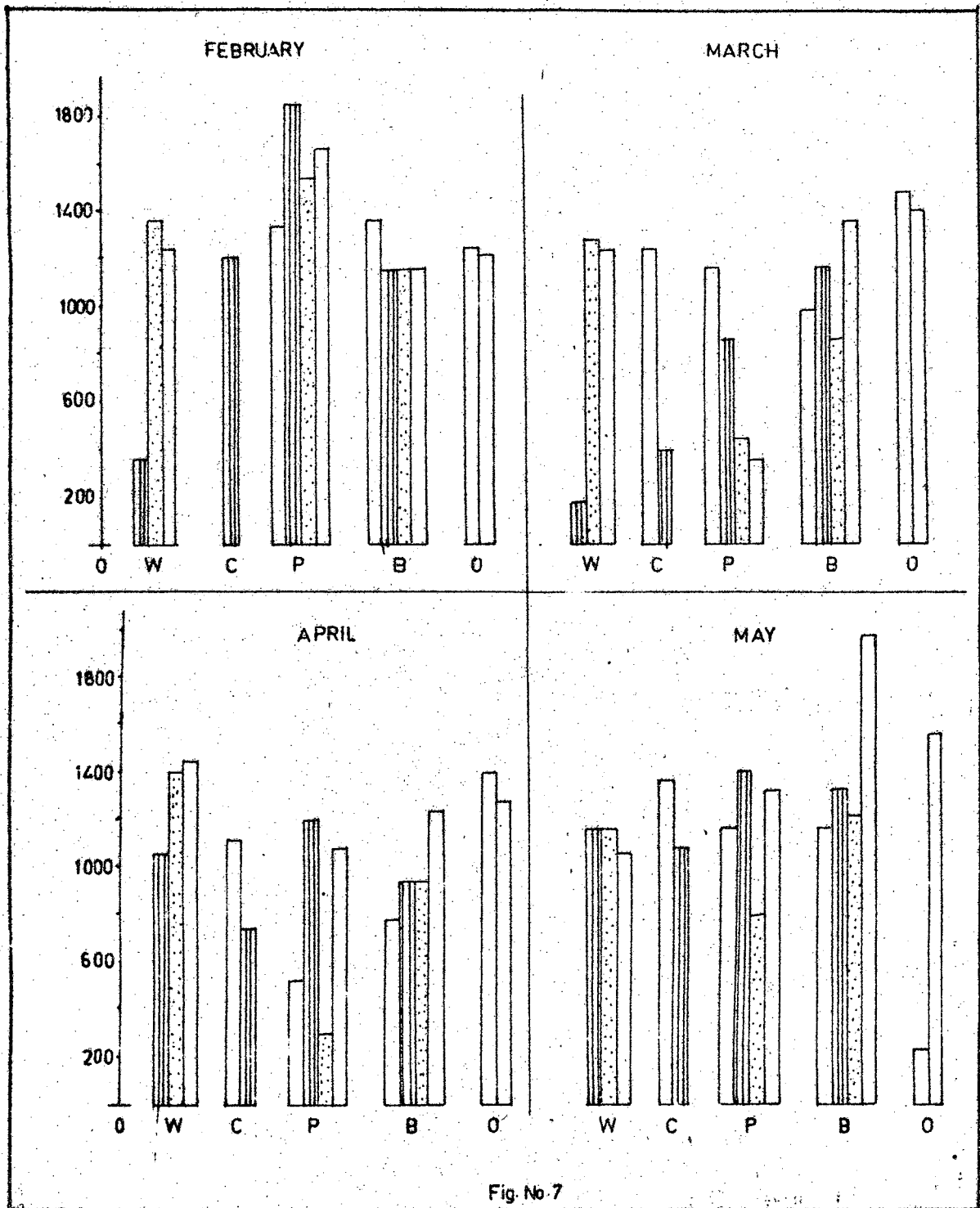
Fig. No. 7

Phosphate Concentration in ppm
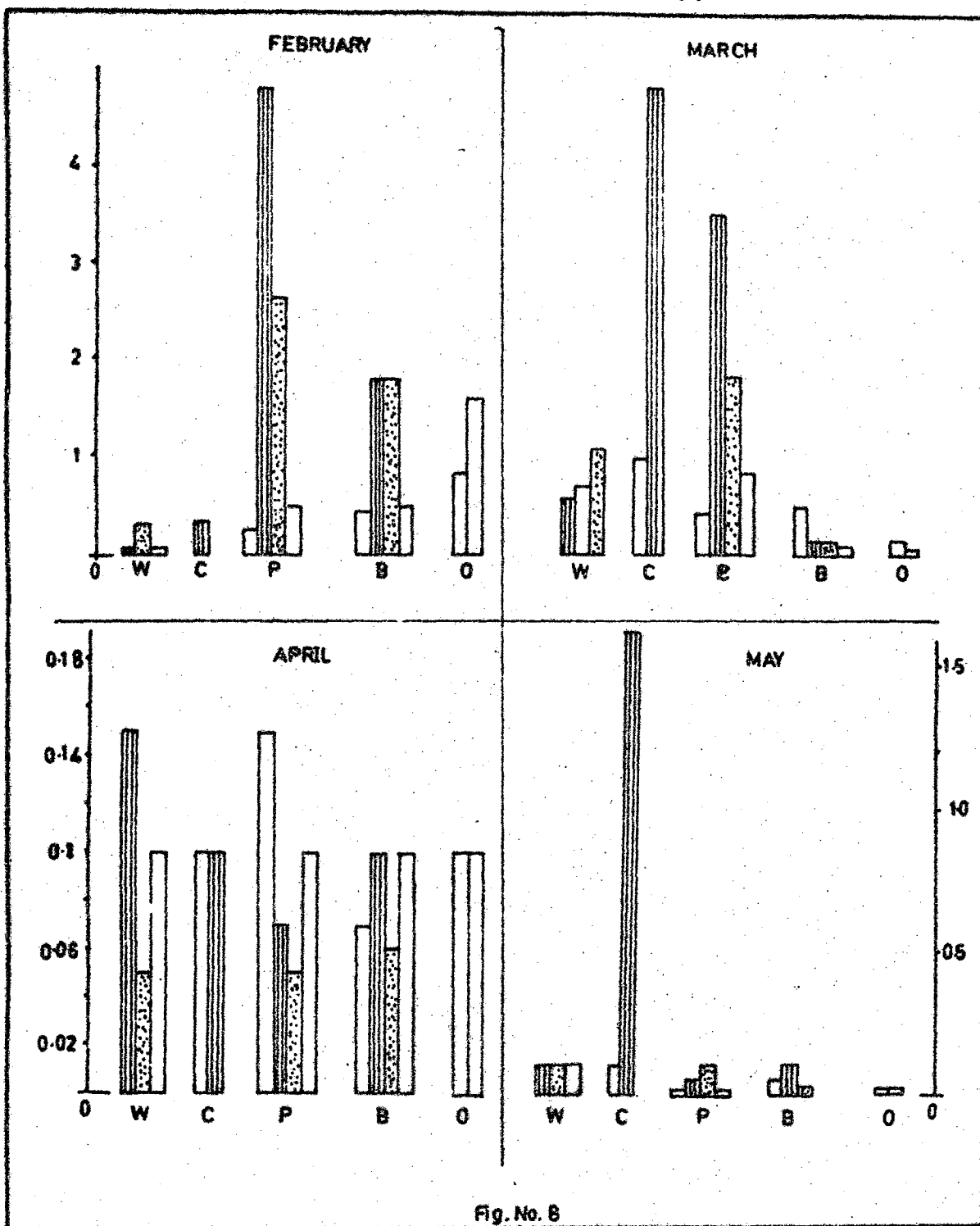
Fig. No. 8

Silicate Concentration in ppm
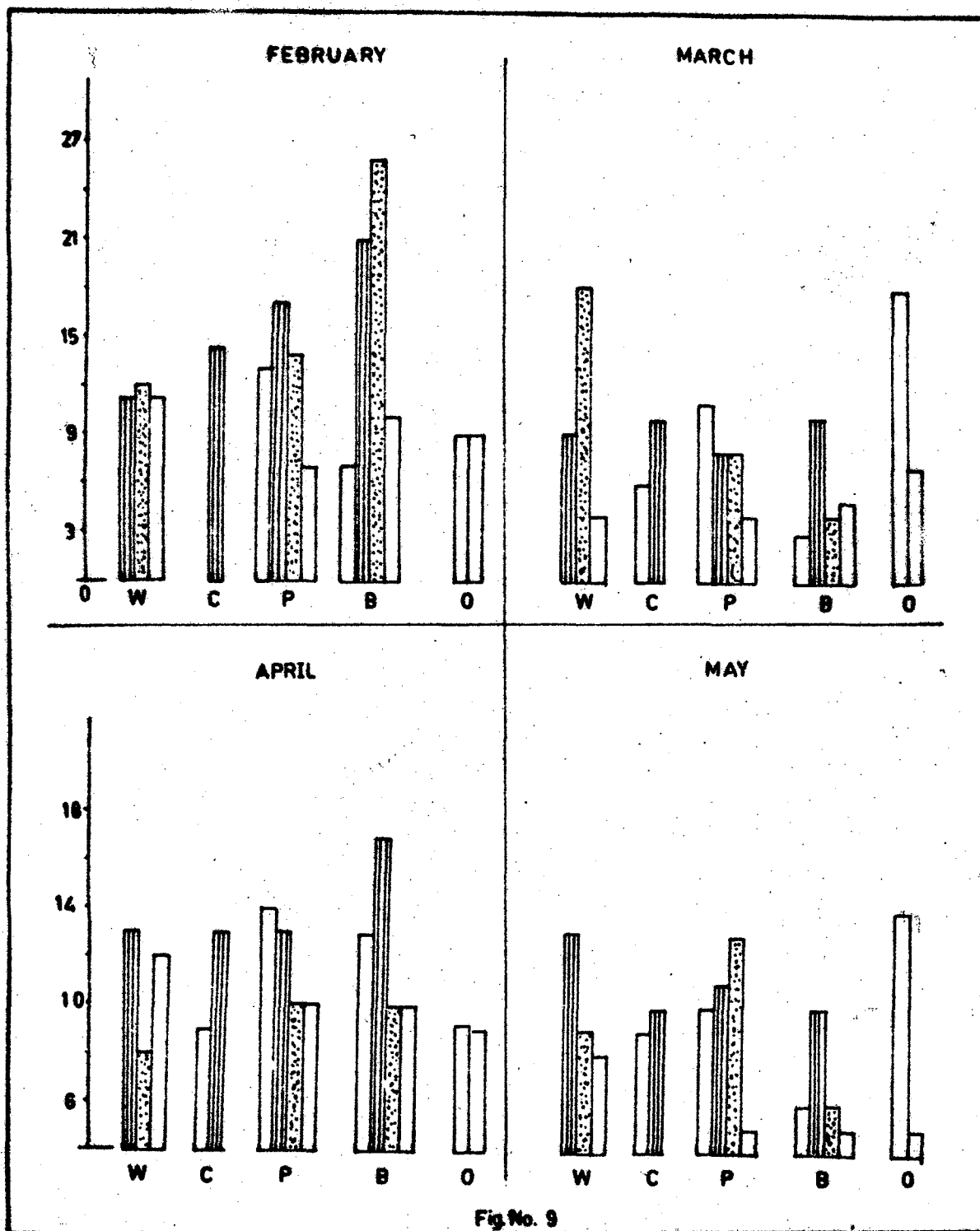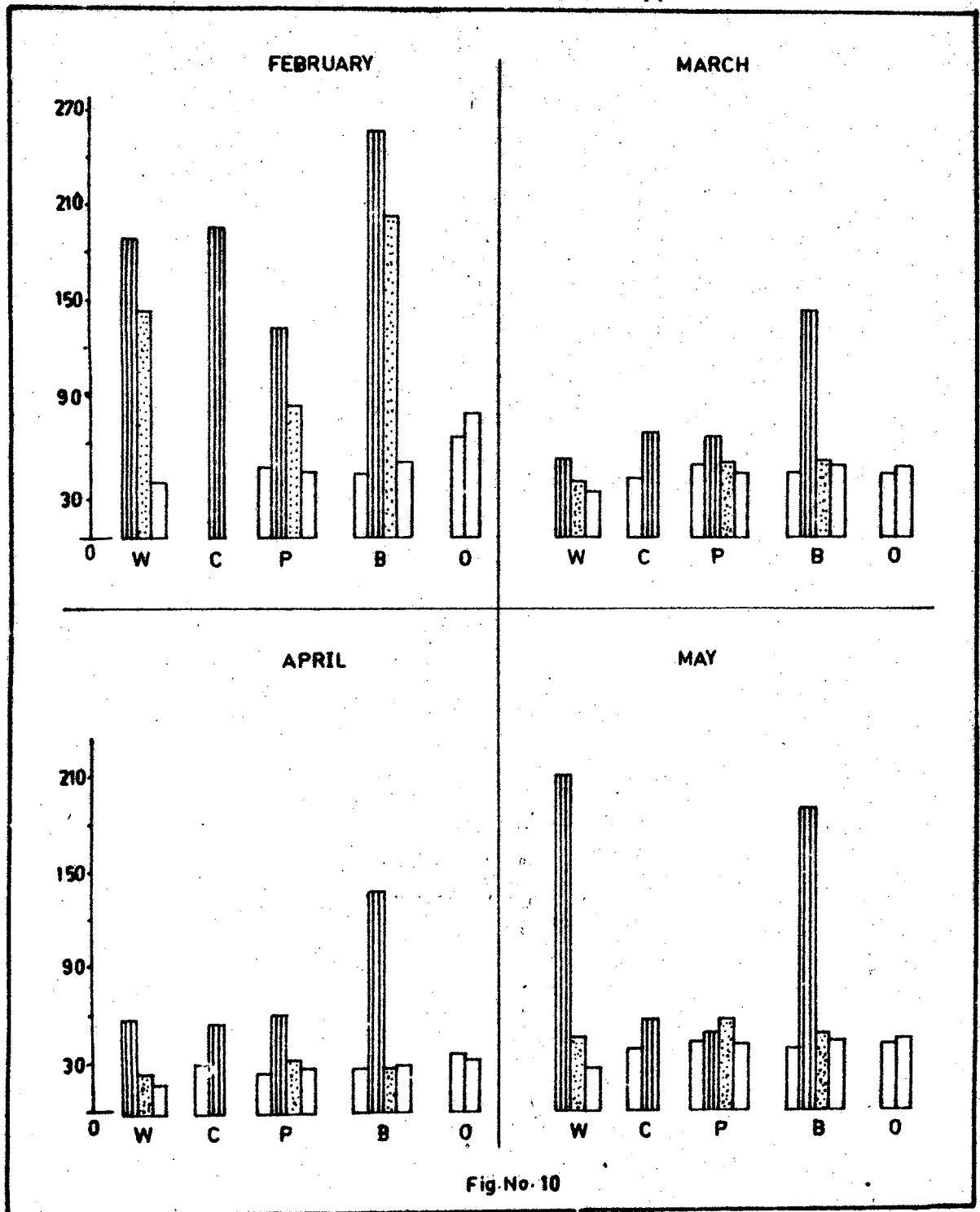
Fig. No. 9

Sodium Concentration in ppm

Fig. No. 10
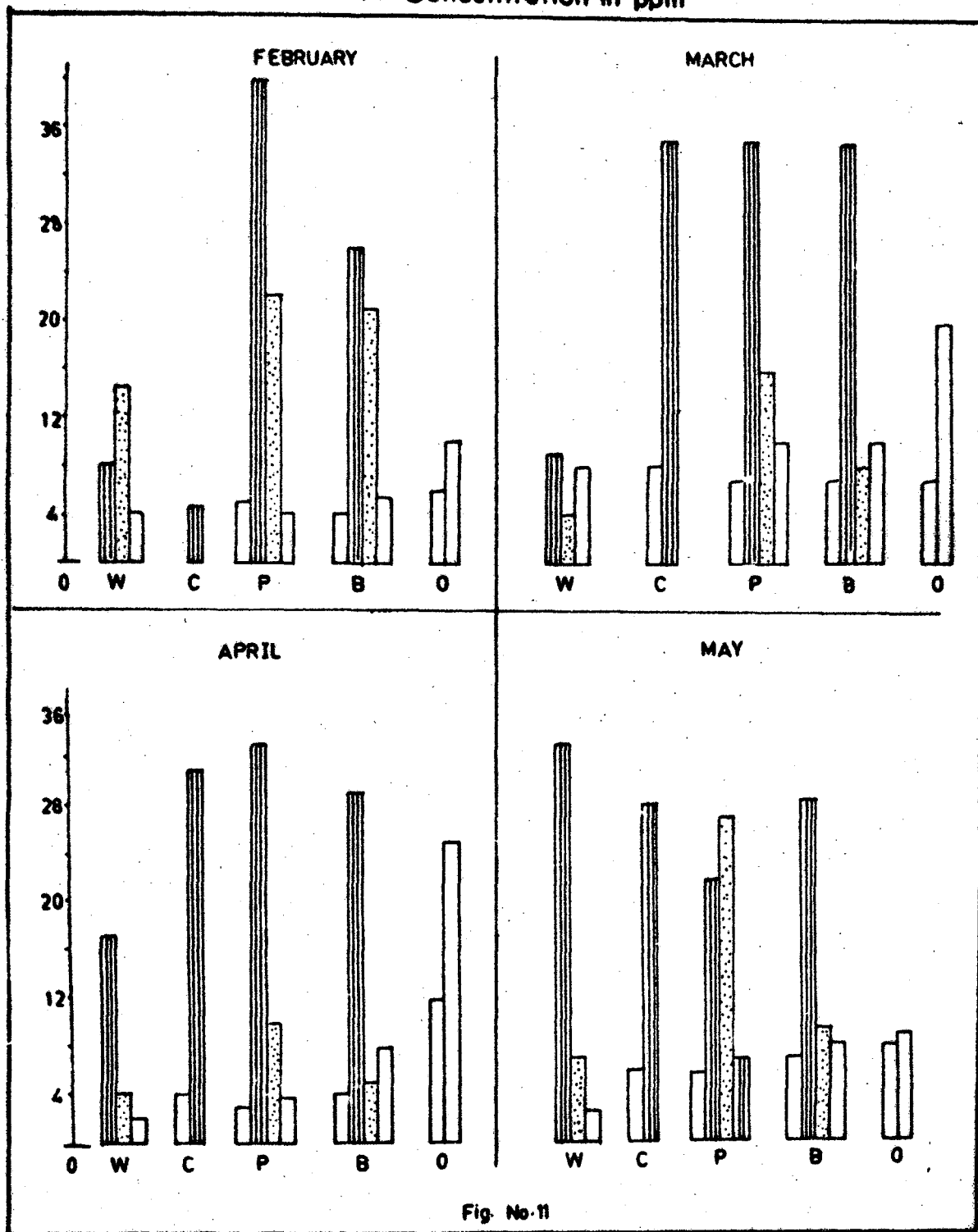
Fig. No. 11

Magnesium Concentration in ppm
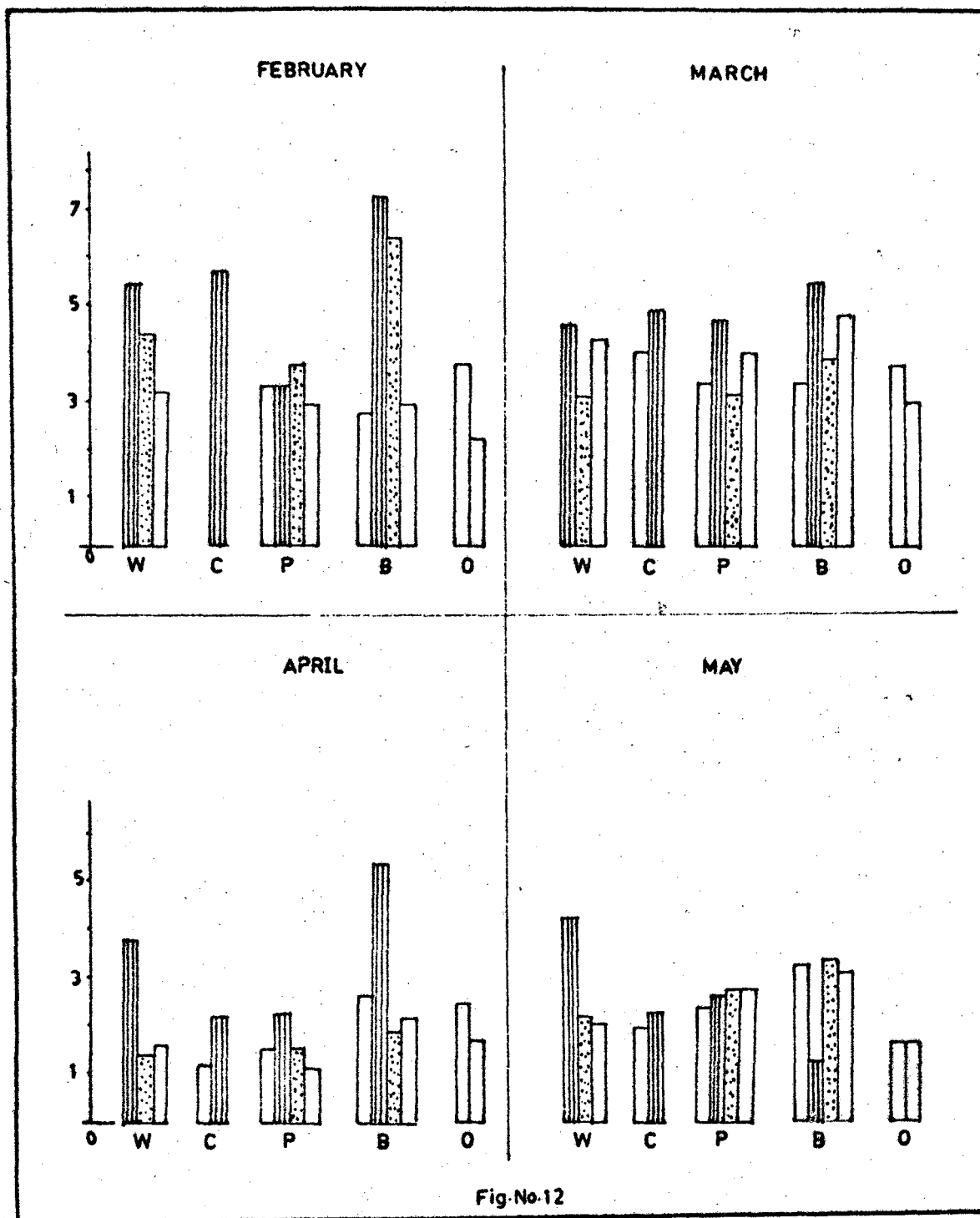
Fig. No. 12

Calcium Concentration in ppm
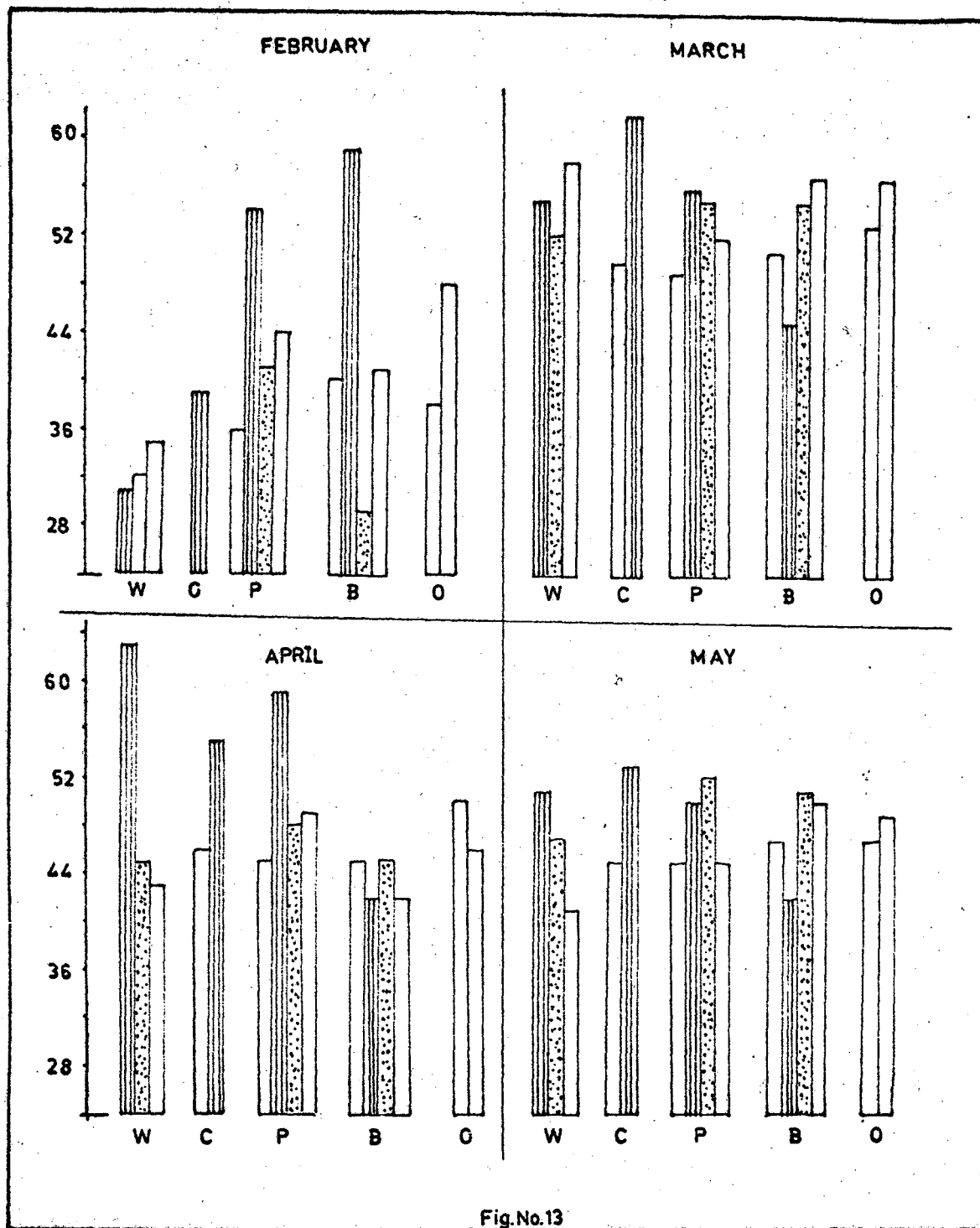
Fig. No. 13

Chromium Concentration in ppm
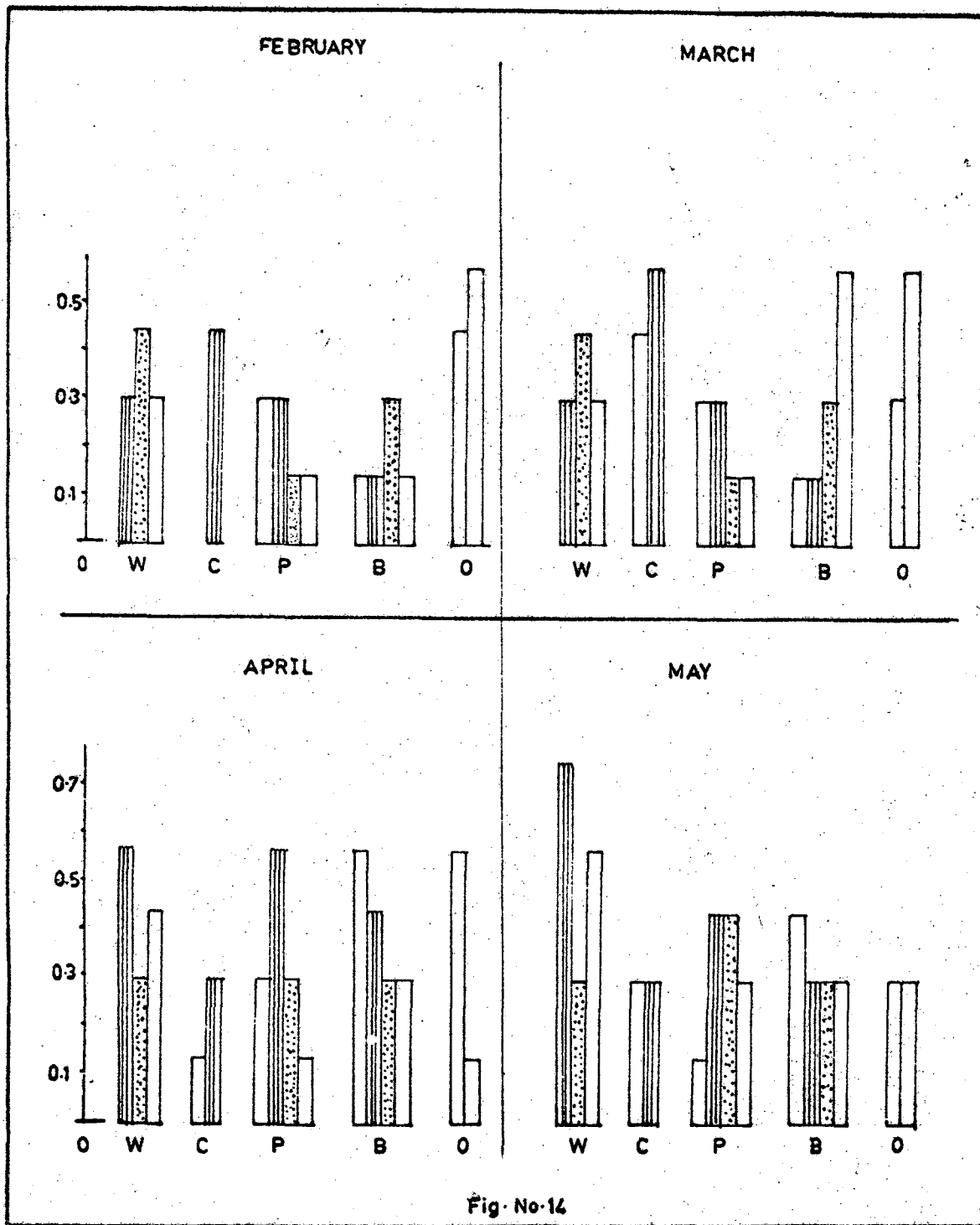
Fig. No. 14

Manganese Concentration in ppm

Fig. No. 15

Iron Concentration in ppm
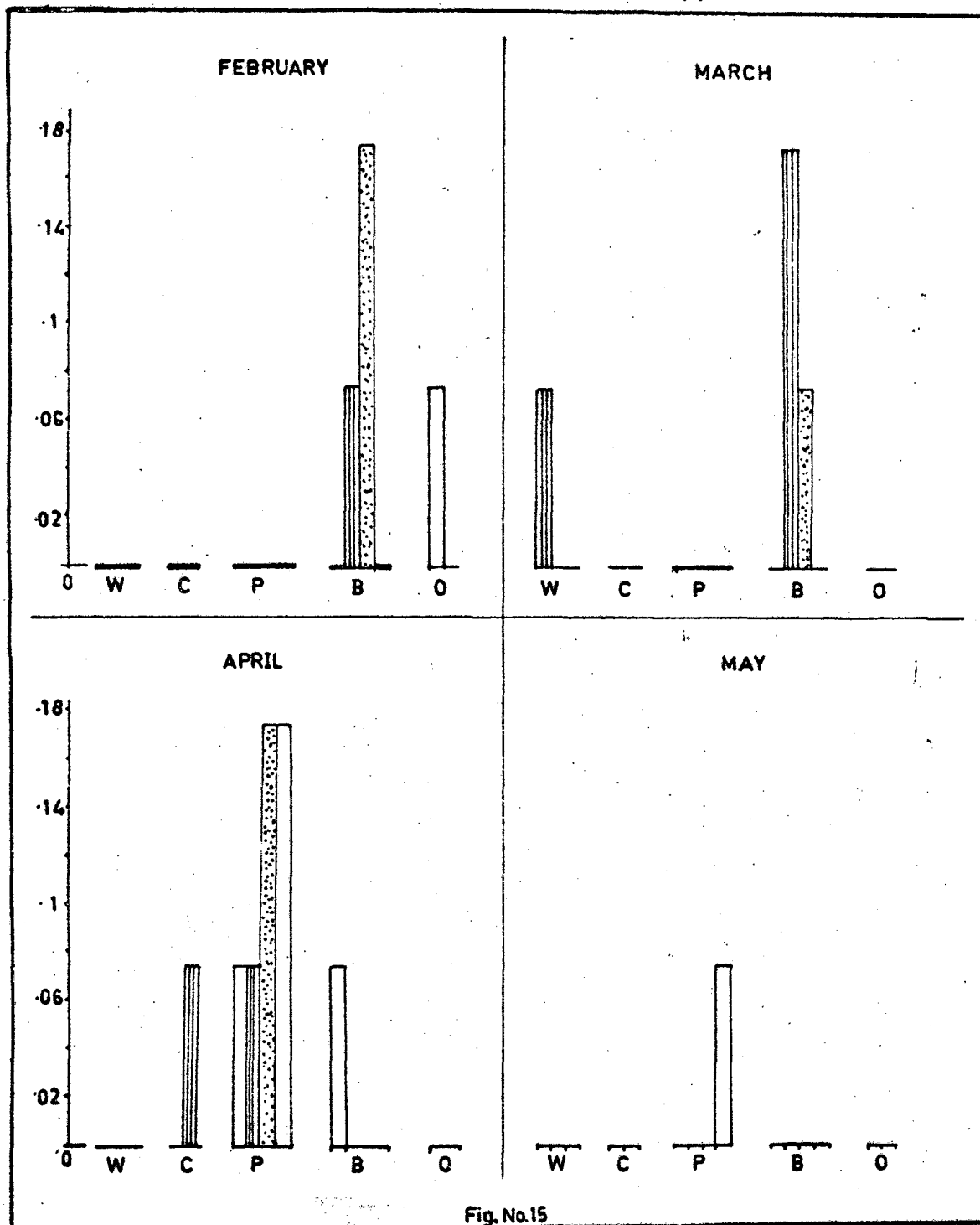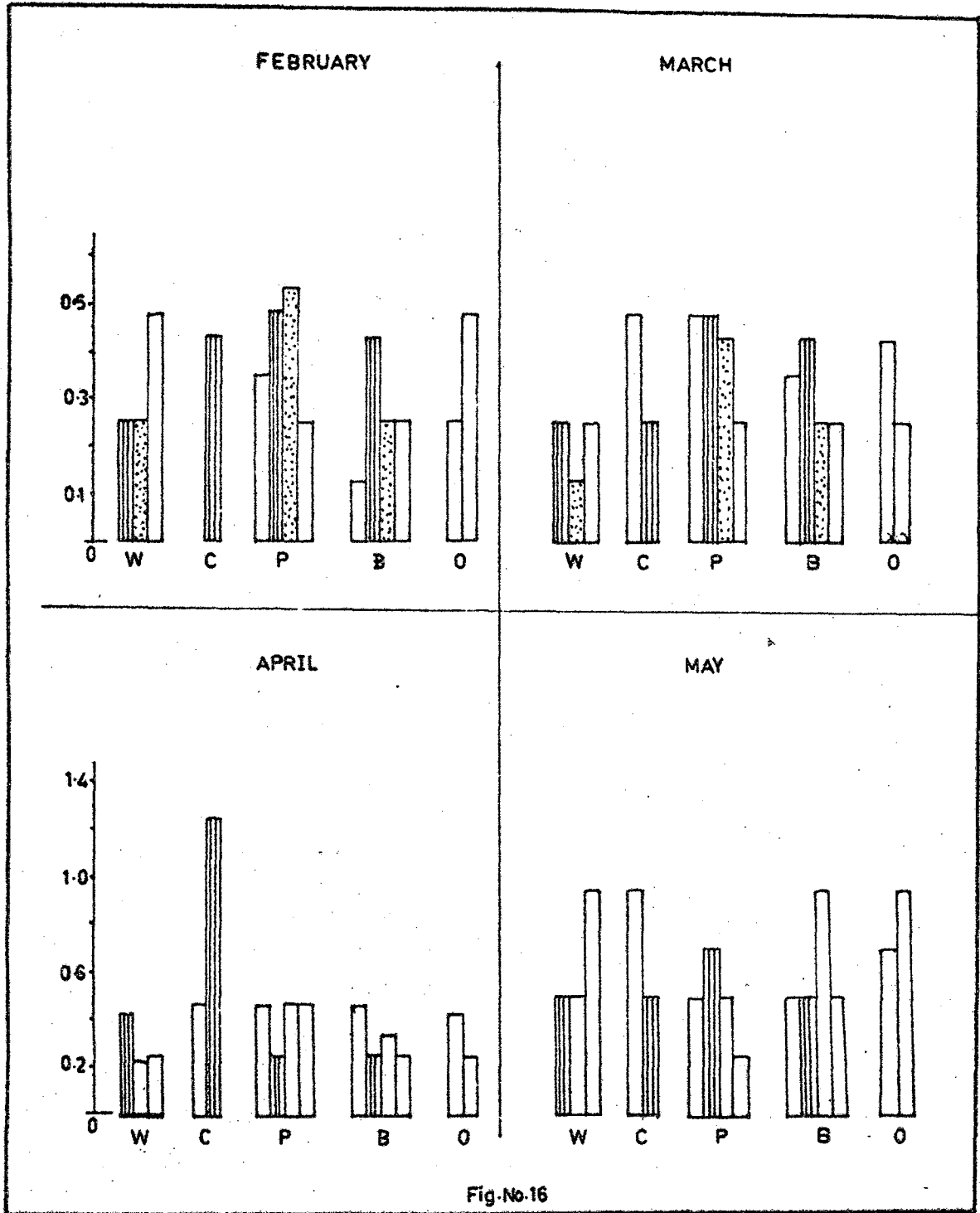
Fig·No·16

Nickel Concentration in ppm
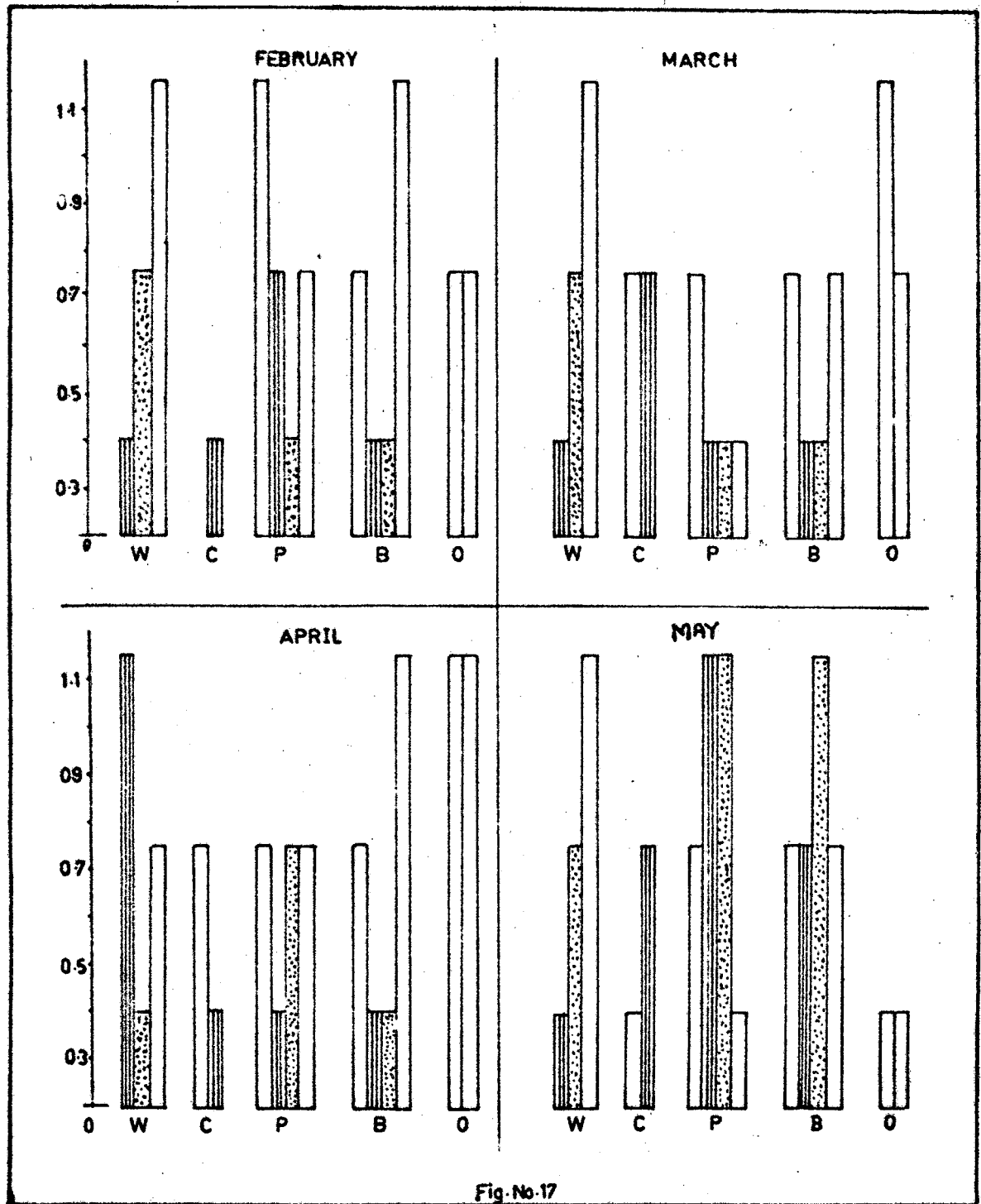
Fig. No. 17

Coppor Concentration in ppm
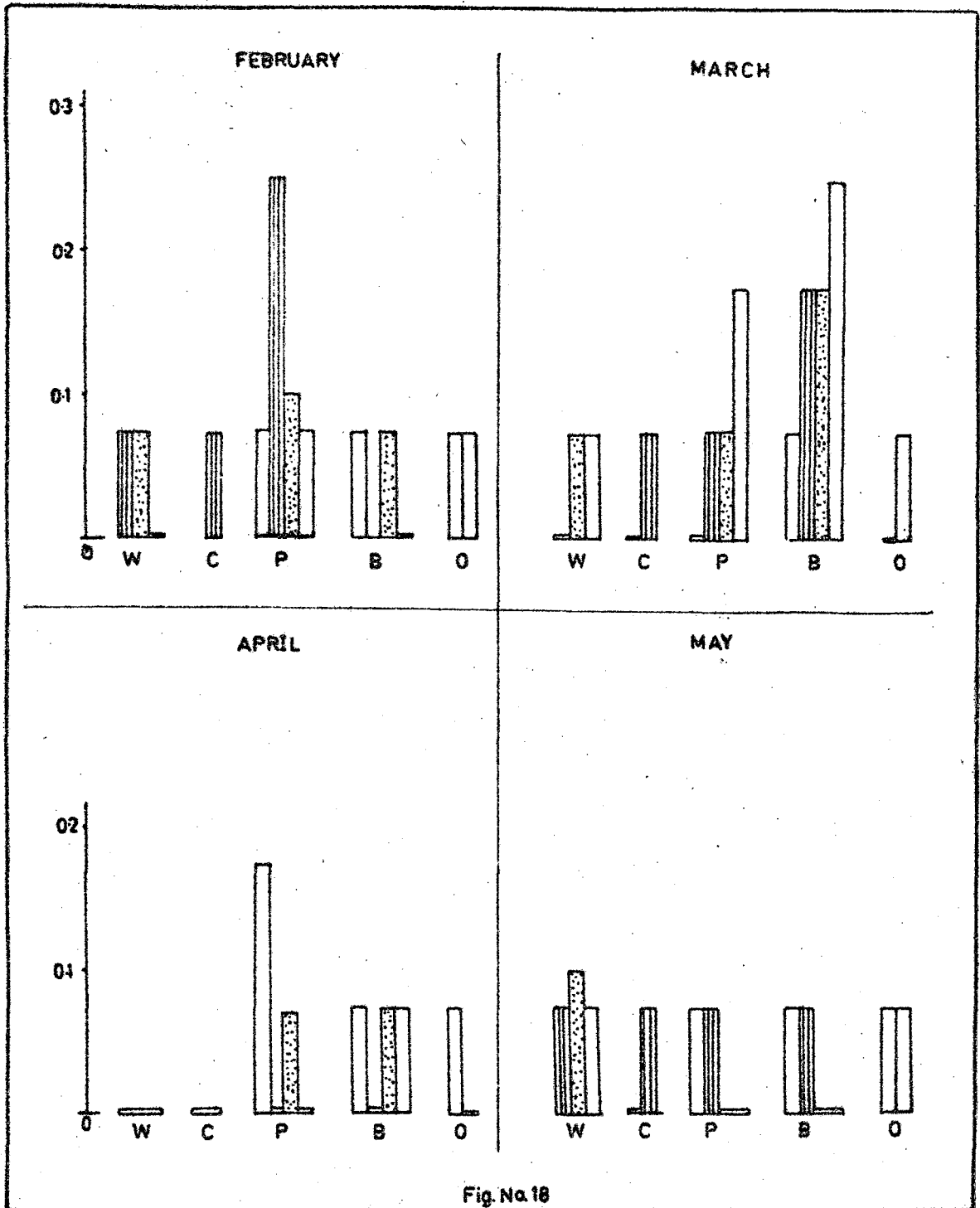
Fig. No. 18

Zinc Concentration in ppm
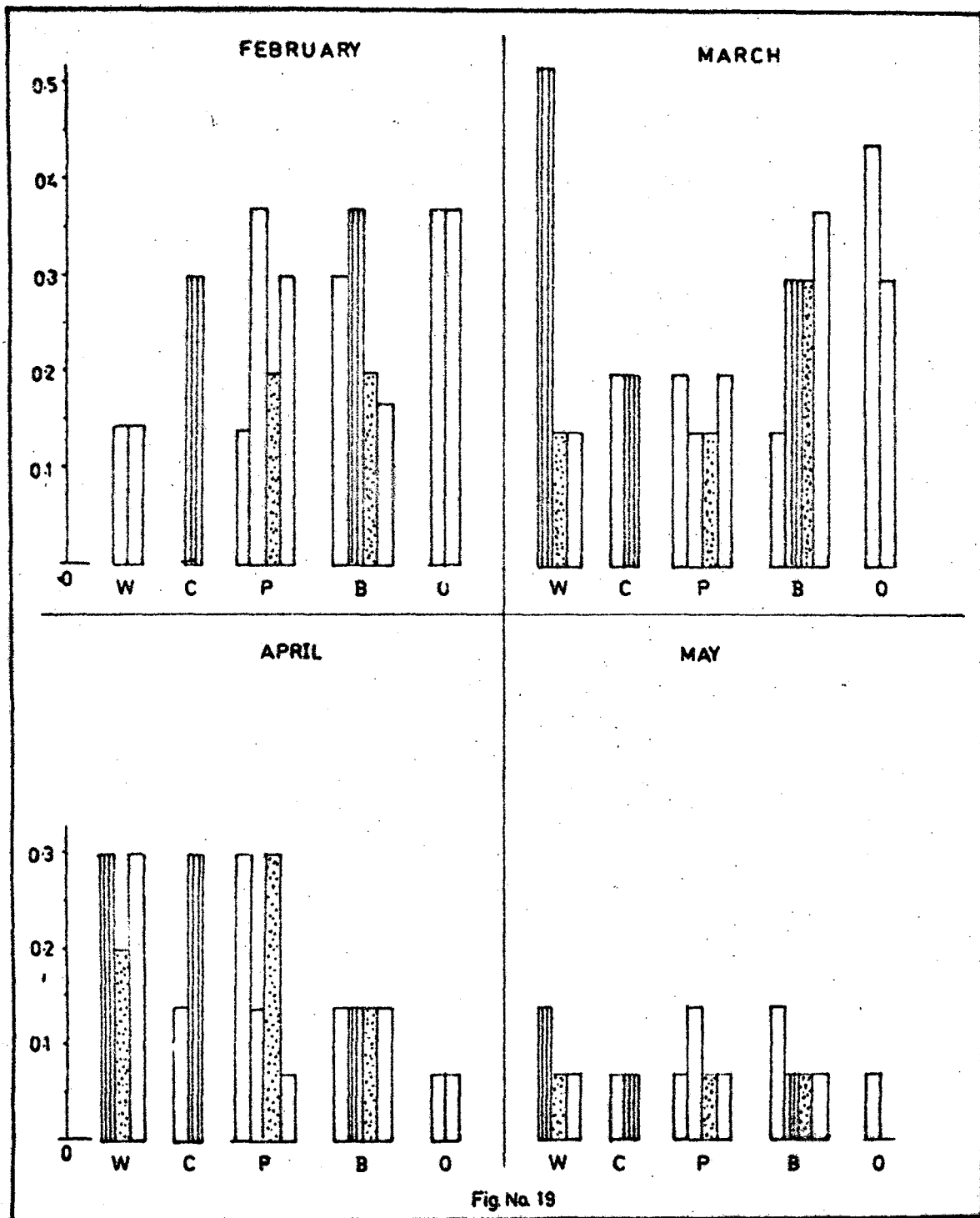
Fig. No. 19

Lead Concentration in ppm
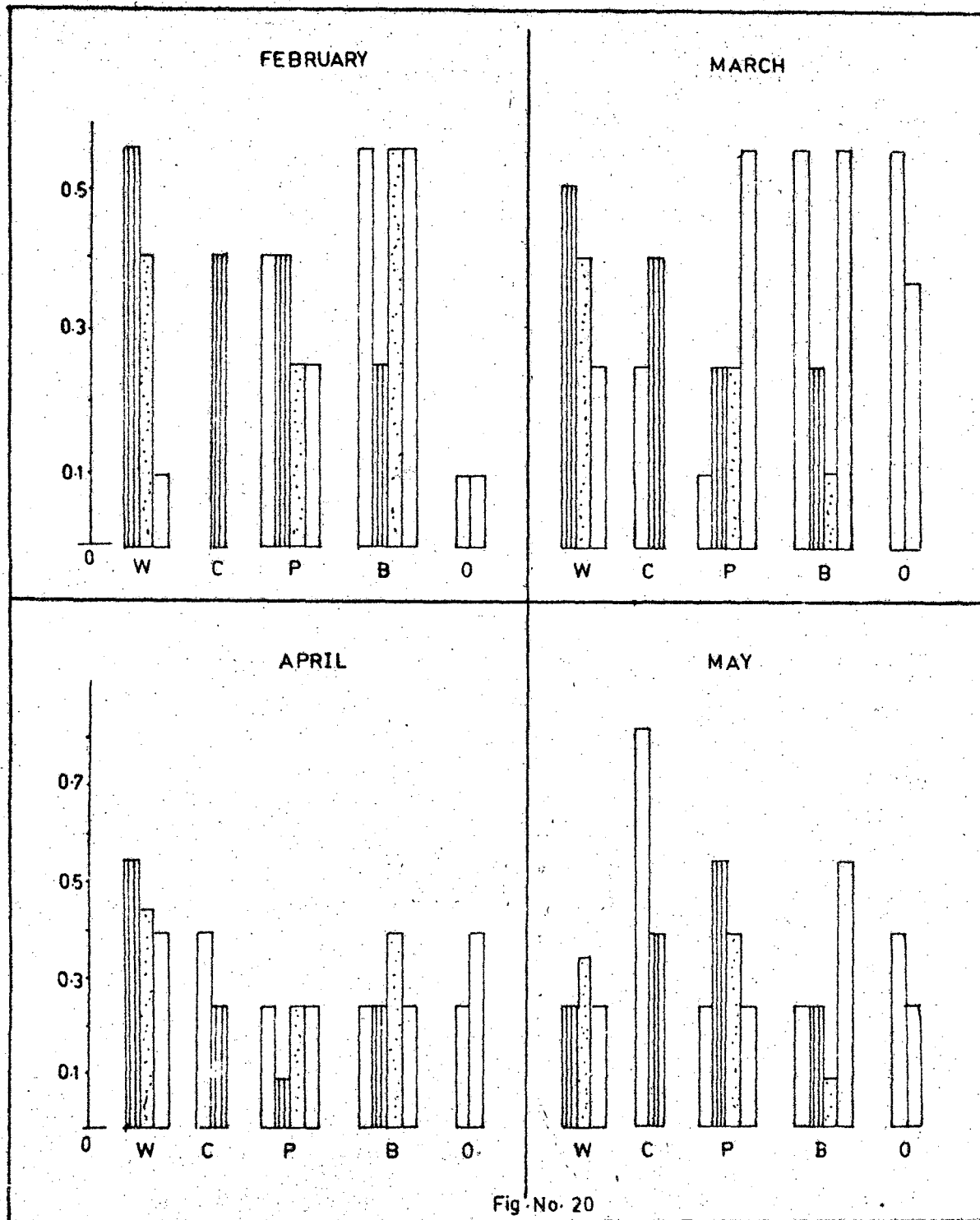
Fig. No. 20

CHAPTER - III

Results andDDiscussion

The variable concentrations in river Jamuna around Delhi, at various stations are presented in Tables 1 to 20 and Figures 2 to 20.

Conductivity and pH: The higher conductivity of the drain water indicates the more ionic concentration than that in river water (Fig. 3).

Our observations clearly indicate that Jamuna river water is alkaline in nature (Fig. 4). These findings are consistent with the previous studies on other Indian rivers (Subramanian, 1979) and the world's average river water (Livingstone, 1963) with the corrected values of Gibbs (1970).

H_2O - CO_2 system in the nature, silicate-mineral equillibria, waste addition from various drains and interactions between trace metals and both organic and inorganic chelating agents in water, alter the pH of water (O'Shea et. al., 1978). However, observed increase in pH in the month of April and May probably due to removal of carbon dioxide (CO_2) in photosynthesis at increasing temperature (Klein, 1977) by algae and heavy plantation on both the sides of river Jamuna.

Total Alkalinity: All natural waters exposed to air, are dilute solutions of carbonic acid due to dissolved CO_2

Reactions of carbonic acid with lime stone, certain minerals like albite (Garrels and Christ, 1965), from partial or complete decomposition of organic waste (Berner, 1971) and waste from petrochemical and coal industry under anaerobic conditions (Subramanian, 1976), release HCO_3^- ions in waters. Besides industrial waste is also one of the major source.

However, Fig. 5 shows, 100 - 500 ppm of total alkalinity in river Jamuna which is much higher than world's average river water (58.4) (Livingstone, 1963). In its upper reaches Jamuna flows over the Krol limestone and Kanker carbonate terrain hence total alkalinity appears to be higher due to weathering (Subramanian, 1979).

The city waste addition from various drains (Table 23) is also a very important factor which causes the increase in total alkalinity of river water. In densely populated Union Territory of Delhi, 3329 industries are located which add the total waste discharge 22800 KL/day (CWPCB, 1979). Usually, alkalies are present in Keir liquor, waste water from cotton wools, paper works, chemical industries, fertilizers, pesticides, electroplating, soap and food products etc.

The total alkalinity observed in all the four drain waters is very high (1190 ppm). It is in agreement with the findings of Eckenfelder (1950), who suggested that alkalinity should be in the range of 1000 - 2000 ppm as $CaCO_3$.

The highest values recorded in Barapullah drain water are in the month of February and May as compared to other drains. It may be because of feldspar, calcite and clay minerals of alluvium soil which yield bicarbonates on weathering, heavy agricultural fields in the surmounding area and waste from applied fertilizers. At low temperature CO_2 dissolves more which breaks down the limestones and increases the alkalinity of water; and releases CO_2 with increasing temperature. Alkalinity is more in the month of February and it is likely that the low temperature in that month may increase bicarbonate ions.

Overall bicarbonate concentration decreases from February to May. It may be because of increasing removal of CO_2 with increasing temperature, conversion of HCO_3^- to CO_3^{--} by algae and green plants, oxidation of NH_3 in domestic waste, conversion of alkali nitrates to carbonates (Klein, 1957).

Chlorides: Fig. 6 shows that chloride contents vary from 15 - 60 ppm in Jamuna river water. These values are very high than world's average river water (7-8 ppm) (Livingstone, 1963).

Chlorides are found in the sand dunes (1075 - 2562 ppm), alluvium (31-282 ppm) and quartzite (61-156 ppm). Sand, composed of feldspar, quartz, gypsum, hornblende, calcite and salt particles on interaction with the rain water dissolve the same producing chloride ions (Wadia, 1978). Jamuna basin is rich in alluvium, therefore chloride contents should also be very high.

Waste from drainage, sewage farm, industries, acid picle liquors are also the major sources of chlorides. 85 - 251 ppm of chloride is observed in all the drain mixings into river Jamuna. Najafgarh drain shows no significant variation in chloride contents which indicate the alkaline waste addition from the industries located in that area, and from domestic waste. However, quite higher amount of chlorides is observed in Barapullah region. Barapullah is a domestic drain. Therefore its sewage may be rich in chlorides because chlorides present as NaCl in the urine to the extent of one per cent. The Barapullah drain covers 138 sq. km. area of South Delhi; which is supplied with most of the tube well waters, i.e., ground water which contains high amount of chlorides. The waste discharge from this region is about 125000 KL/day (CWPCB, 1979) suggests the presence of high chloride contents. In addition, chlorides may be derived from agricultural waste in that region (Biyani, 1979). The amount present depends on the chloride content of the water supply, waste from food products, flow of the water discharge etc.

The flow discharge of drains (Table 23) varies at different mixing points of river hence the changes occur in the river basin. Chloride content increases significantly from Wazirabad to Okhala may be due to the addition of these different drains. Since river Jamuna passes through densely populated area

and increase or decrease of salt concentrations in the down stream direction simply reflects man's activity (Subramanian, 1979).

Sulphates: The sulphate concentration in the river water is shown in Fig. 7. It averages 200 - 2000 ppm whereas the world river water average is 11.2 ppm. Generally sulphates present naturally in all waters as a result of solvent action on gypsum, pyrite, Galena, chaleopyrite, sphelerite, unhydrite and it also present as a final oxidation products of dilsulphides, sulphites and thiosulphates (Balusu et. al., 1964). H_2SO_4 in atmosphere is derived from dust particles of sulphur, oxidation of SO_2 and H_2S gas, burning of a coal and oil. River water and drain water contain 11.2 ppm and 2 ppm of sulphate (Wedepohl, 1970) and it is variable in quartzite (75-750 ppm), alluvium (200-831 ppm) and sand dunes (665-2531 ppm).

Concentration of sulphate in the river also varies according to the waste discharge and addition of the sulphate ions along with the contribution from alluvium region. Tube well water contains high sulphates and they could also be the possible source.

The high sulphate concentration observed in all the four drains varies from 400 - 1840 ppm may be because of waste from sulphate pulps, pickle liquors, electroplating, tannary effluent and chemical industries from Najafgarh and other industrial areas.

The higher concentration is observed in power house drain compared to other drains indicates fairly large amount of sulphates in the waste from power house station. The coal ash contains upto 20% pyrite, which on dissolution gives sulphate in water (Brown et. al., 1976). Sulphate concentration in the river water increases downstream as drain water itself shows higher concentration of sulphates and hence at the mixing points of drains in the river Jamuna.

Phosphates: The data obtained for the phosphate concentration in the river Jamuna is graphically presented in Fig. 8. It ranges from 0.015 - 2.68 ppm and increases from February to April.

The phosphate is a major plant nutrient and major sources of it are phosphatic minerals of rocks, sedimentary phosphate beds, decay of the organic materials like coal, petroleum, plants, bones, fertilizers and waste water from detergents, sewage, plating industries, anodizing, phosphodizing, washing, human and animal excreta.

The increase in phosphate concentrations also possibly due to the addition of waste discharge from domestic drains which also contain waste water from tube wells (4 - 17 ppm phosphate in ground water) (Biyani, 1979).

Phosphate concentration observed in all the drains is in between 0.01 - 4.85 ppm which is higher than that in river waters

It may be because in sewage hydrolysis of phosphorous is more rapid (Devey, 1973) and (Lewin, 1973) also observed the higher concentration of phosphates in sewage (6 - 8.9 ppm).

The higher concentrations of phosphates may also be due to the ion-pair formation with metal ions of phosphorous species which in some instances be sufficiently stable to increase the phosphate solubility (Jenkins, 1971). The highest values observed in the civil mill and power house region, probably, may be because of domestic/industrial waste water and coal ash dumped from power plant which contains 0.001 - 0.1 ppm phosphorous respectively (Francis, 1960).

Silicates: Fig. 9 shows the silicate concentration in river Jamuna (3-18 ppm) and in the drain water (8-21)ppm). There is not much variation in silicate concentration in river and drain water because, the whole Jamuna river basin is occupied with recent alluvium and chemical equilibria of this system are controlled by the activities of dissolved silica in the form of H_4SiO_4 (Dalavi, 1978).

All natural waters and waste waters contain many types of buffers i.e., carbonates, silicates, hydroxides, ammonia, ammonium ion etc. In addition to this most natural water contains silicates relatively low concentration, free or combined with other substances and at slightly higher pH, bases do tend to dissolve sand to some extent.

Besides these, minerals like forsterite hydrolyzes giving H_4SiO_4 in water

$$Mg_2SiO_4 + 4 H_2O \longrightarrow 2 Mg^{++} + 4 OH^- + H_4SiO_4 \quad \text{and}$$

$$MgSiO_4 + 4 H_2CO_3 \longrightarrow 2 Mg^{++} + 4 HCO_3^- + H_4SiO_4$$
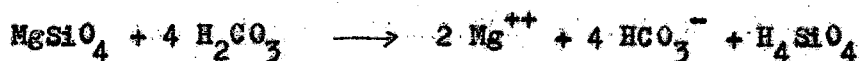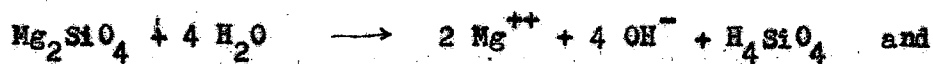
K- Feldspar, Na- Feldspar, Kaolinite, montmorilonite, illite are also the major sources of silicates.

The time variation observed in the silicate concentration may be due to changes of Kaolinite to Na-Feldspar longitudinally due to increase in Na^+ concentration which has been reported recently by Dalavi (1978).

Another possible reason is that as montmorinolite is not a stable phase, it changes to illites and further Kaolinite resulting in the variation of silicate concentration in the river basin.

Major Cations

The concentrations of Na^+, K^+, Mg^{++} and Ca^{++} in Jamuna river at different locations is shown in Figs. 10-13. The river water averages 15 - 77 ppm Na^+, 2-24 ppm K^+, 1-5 ppm Mg^{++} and 28-57 ppm Ca^{++} whereas drain water averages 40 - 255 ppm Na^+, 4 - 40 ppm K^+, 1 - 8 ppm Mg^{++} and 32 - 63 ppm Ca^{++}; which in turn adds with the total waste into river Jamuna, and therefore increase the total concentration of metal ions in the river water.

Observed concentration of Na and Ca is very high as compared world's average river water (6.3 ppm for Na^+ and 15.1 ppm for Ca^{++}). The natural sources for major cations are as follows which determine mainly their concentration in the river water.

Na^+ - Weathering of plagioclase, pyroxene, hornblende, evaporite minerals and rain water (2 ppm) (Davis et. al. 1967).

K^+ - Weathering of orthoclase, microcline, biotite, K-feldspar, leucite and other K-bearing minerals and rocks like granites, syenite, arkose, mica schist etc. and rain water (0.1 ppm) (Davis et. al., 1967).

Ca^{++} and Mg^{++} - These cations are found in abundance in the earth's crust. The various minerals of these ions are calcite, magnesite, dolomite, anhydrite, gypsum, feldspar, pyrosenes, amphiboles etc. and rain water (10 ppm Ca^{++} and 0.1 ppm Mg^{++}) (Wedepohl, 1970).

The observed cations in river may also be because
of the addition of domestic waste, sewage, chemical industries,
viscoserayon manufacturing, chrome tanning, lime, Keig liquor,
etc.

River Jamuna is occupied with recent alluvium soil
which contains clay and feldspar. Among the feldspars, plagio-
clase weathers faster than K-feldspar and calcic plagioclase
weathers faster than sodic-feldspar. Therefore, concentration of
Na and Ca is higher than Mg^{++} and K^+ in river water.

The variation observed in the major cation concentrations
in river, at mixing points of drain as well as in drains, may be
because of change in flow rate of the drain and volume of river
water which differ at different sampling stations. Total increase
in concentration of these cations is more in the month of May
possibly because of high temperature, lower volume of water and
fertilizers from agricultural waste.

Sodium concentration is higher whereas K^+ concentration
is less as compared to Ca^{++} and Mg^{++}. Domestic and industrial
drains carry higher amount of sodium which on addition increase
the sodium concentration in river water. The K^+ ions may be
absorbed by alluvium which is dominantly made up of clay, thus
reducing the K^+ content of the river water (Grim, 1947).

The higher concentration of the major cations is found
in the region of Power House and Barapullah station. These higher

values may be due to disposal of pulvarised fuel ash in water from power house station. Barapullah is one of the biggest drain and two power stations are housed upstream of this Barapullah region. Generally ash contains all the major cations, along with other heavy metals and rare earths from various coal sources (Brown et. al., 1975).

Trace elements

There is a great deal of interest in the presence of trace elements in the environment and the quantities to which man is exposed. Trace elements are nothing but which those occurring at concentration in natural fresh waters below 1 mg/liter.

Several trace inorganics of waste waters and natural waters are important in establishing the water quality. The concentration of inorganic substances are increased both by geologic formation with which the water comes in contact; and by the waste water treated or untreated. Natural water dissolves some of the rocks and minerals resulting an increase in concentrations.

Trace quantities of many metals such as Cr, Mn, Fe, Cu, Zn, Ni, Pb, Cd and Hg are important constituents of most waters. Some of these metals are necessary for growth of biological life and absence could limit the growth. While the presence of any

of these metals in quantities will interfere with many beneficial uses of the water because of their toxicity. Therefore, it is frequently desirable to measure the concentration of these metals.

Although many surveys of total heavy metals have been concluded (Durum, 1974; Kubota and Others, 1974), few have been concerned with metal specification. The physical and chemical state of trace metals must be considered when the availability and toxicity of metals to aquatic organisms are concerned. (Mc Kee and Wolf, 1963; Harlung, 1973; Brown and Others, 1974; Clubb, 1974).

Naturally occuring inorganic ligands such as humic acid and fulvic acid can form complexes and chelates with metals and thereby affect transport, availability and toxicity of trace metals (Manning and Ramamoorthy, 1973; Beck and Others, 1974; Webber et. al., 1974; Elder, 1975; Giesy et. al., 1977).

Naturally the source of trace elements is from various minerals present in the environment (Krauskopf, 1967).

Figures 14 - 20 show the trace metals, $Cr(0.14 - 0.57$ ppm$)$, $Mn(0.00 - 0.17)$, $Fe(0.12 - 0.52$ ppm$)$, $Ni(0.4 - 1.15$ ppm$)$, $Cu(0.00 - 0.175$ ppm$)$, $Zn(0.07 - 0.44$ ppm$)$ and $Pb(0.1 - 0.82$ ppm$)$, concentrations in the river Jamuna at various locations. Whereas the overall concentration in all the drain waters observed for

all the trace metals, $Cr(0.15 - 0.75)$, $Fe(0.2 - 1.25$ ppm), $Ni(0.4 - 1.15$ ppm), $Cu(0.00 - 0.25$ ppm), $Zn(0.07 - 0.5$ ppm) and $Pb(0.1 - 0.56$ ppm) is higher than that in river Jamuna. However, detectable concentration of $Mn(0.075 - 0.17$ ppm) is found at very few locations.

Most of the industries in India are inorganic oriented, therefore the industrial effluent is one of the major sources of the toxic metals. All types of industries like textiles, dyeing, finishing, electroplating dry cleanings, chemicals industry, fertilizers, pesticides, printing, soap, food products, rubber and plastic etc. are located in Najafgarh, trans-Jamuna MCD and Kalkaji areas. It clearly indicates that the waste water from these industries carries substantial amount of trace metals which in turn adds into the river Jamuna. Apart from these trace metals are mainly derived from various minerals present in the environment by weathering (Krauskopf, 1967).

Different concentrations of trace metals are observed at different sampling stations in river and in different drains. These variations depend on time of collection, type of waste addition into the river, volume and temperature of water, discharge of drains, weathering etc.

The concentration of Mn^{++}, Fe^{++}, Ni^{++}, Cu^{++}, Zn^{++} and Pb^{++} is more in the river at power house and Barapullah region, due to disposal of pulvarized fuel ash in Jamuna river from

power house station and ash contains all the heavy metals
in good proportions (Brown et. al., 1975) whereas Barapullah
is the biggest drain which is supplied with most of the tube
well waters, i.e., ground water which contains high amount of
trace metals (Turekian et. al., 1977) also studied the metal
concentration in Neuse river in North Carolina reasonably free
from municipal and industrial pollution and he found that the
changes in concentration were due to ground water.

It is interesting to note that chromium concentration
increases, with few exceptions, from February to May, probably
due to increase in temperature and decrease in the volume of
water in river Jamuna and observed lower values likely because
of reduction of chromium VI to chromium III, thereby affecting
its transport in water (Gloyana et. al., 1971).

Lower concentrations observed for the trace metals in
the month of March and May as compared to February and May be
because of more bacterial growth at increased temperature.
Silvey (1967) also observed that greater the biological activity,
lower the trace metal concentration.

In addition to this Fe and Mn form hydroxides in aerobic
conditions and thus lower the concentration in water.

The lower concentration observed in case of Ni^{++} and Cu^{++}
favours the point that there could be decrease in trace element

concentration in the flow of river water (Durum et. al., 1963). Formation of complexation of Ni^{++} and Cu_a^{++} with naturally occurring fulvic or humic acids which also plays a potentially important in their effect on the movement through natural water influencing their solubility (Waris, 1953; Jenne, 1968; Duce et. al., 1972; Zitko,,1973; Manning and Ramamoorthy, 1973; Beck et. al., 1974; Webber et. al., 1974; Elder, 1975; Whitfield,et. al., 1976; Glosy et. al., 1977).

There is not much variations in Cu^{++} concentration in river Jamuna and in some drains. (Sylva,(1976) showed that the chemical conditions of most aquatic systems are such that even if relatively large levels of Cu^{++} are present, the process of hydrolysis, precipitation complexation and adsorption will very often be reduced the free Cu^{++} to ion concentration to very low values.

Complexation of metals will increase with increasing pH in a carbonate medium with hydroxo or carbonato ligands (O'Shea et. al., 1978). The observed alkaline pH of the river Jamuna shows the significant presence of bicarbonate ions which will enhance the complexation phenomenon in case of trace metals especially Cu which is generally associated with organic matter in the river water (Florence, 1977).

The lower values obtained from February to May,,which are decreasing in case of Zn and Pb probably due to increase in the pH level of water in the river. O'Corner et. al. (1964) showed that Zn concentration decreases with increasing pH.

The concentration of metals observed, at upstream of river Jamuna is less than that in river Jamuna at Wazirabad. However, the upstream region is free from industrial and domestic input. Studies of Dalavi (1978) at Kalanour, a place near the origin of Jamuna river, show that presence of metals in river water is due to the physical weathering.

The metal concentration in the river Jamuna increases downstream from Wazirabad which is an entering point of river within the Union Territory of Delhi. Our study reveals that drain waters carry fairly large amount of metals as compared to river water which inturn add the same in river Jamuna. It clearly indicates that variation at downstream of the river is due to addition of industrial, domestic and other waste water through seventeen drains (Table 23) connected to river Jamuna from Wazirabad to Okhala. Similar results are also reported for number of other rivers (Gibbs, 1967, Grove, 1972, Subramanian, 1974, 1979).

Since river Jamuna around Delhi passes through densely populated and industrialized areas, the increase or decrease of salt content in the downstream simply reflects man's interference with the natural geochemical cycle.

It is surprising to note that chemical compositions
of the river Jamuna is, comparatively higher than that of world's
average river water (Livingstone, 1963).

CHAPTER - IV

Impact of Drain Discharges on Water Quality
of River Jamuna

Study on metal pollution is carried out for the
first time in Jamuna river. Within the Union Territory of
Delhi, water supply is mainly from Wazirabad and Okhala.
The water is also supplied by the tube wells and ranny wells
to some part of Delhi.

Out of an total estimated of 12,000,000 KLD (CWPCB, 1979)
water consumed, the total waste discharge generated in Delhi
is about 9,60,000 KLD (CWPCB, 1979). Only 46.4% of this total
waste water is treated and rest of the untreated waste water
finds its way into river Jamuna through seventeen drains around
Delhi (Table 23), out of which seven major drains alone carry
5,10,000 KLD and hence contribute 94.9% of the total unheated
wastes from industries, domestic and other sources.

Though there are major seven drains, study had been
done only for four drains (Fig. 1). The total waste discharge
and average concentration of metal ions are given in Table A.
From these observations, it is observed that Najafgarh and Power
House drains contribute measurable quantity of Cr^{+6}, Ni^{++}, Cu^{++},
Zn^{++} and Pb^{++}, however, civil mill drain adds Fe^{++} and Cu^{++} in
good proportion.

Najafgarh drain area covers about 2000 industries, which produce different type of wastes from various industries located and alone contribute 55.6% of the total waste water, which streams into river Jamuna. Excess quantity of coal ash addition to river Jamuna is unknown, however, our analysis proved that power house drain adds large amount of trace metals into river water apart from phosphate, sulphate, chlorides, etc.

Very high concentration of metals have been observed in drain waters compared to river. They are present in following order:

$$Ni > Cr > Fe > Pb > Zn > Cu > Mn.$$

The total waste discharge from Najafgarh is 28800 KLD. The observed lower concentration of metals at downstream may be because of dilution effect, after mixing into river water. However, higher concentration of metals are found at Power House region due to disposal of coal ash and waste water from trans-Yamuna MCD, which is also a big industrial drain.

Metal concentration increases longitudinally from Power House to Okhala region due to waste, addition from Barapullah region which covers the waste water from industries located in Greater Kailash, domestic sewage, ground water waste etc.

Okhala region also receives waste water from tube wells, sewage plant, industries while metal concentration variation

found in Agra Canal is the effect of addition of waste
from Kalkaji drain which is mixed into the Agra Canal and
wastes from industries on Badarpur Road. The ionic
concentration of metals vary according to the season, along
with the other environmental factors. Metal concentrations in
the month of February was less because Jamuna was flooded due
to heavy rains in the early January. It seems that high
velocity and large volume of water diluted the metal concentration
in the river. However, in the month of March, flood was reduced
therefore, volume of water was less which resulted into increase
in metal concentration in that month.

Metal concentration observed in the month of April and
May is little higher.

The total variation observed in the metal concentration
in the river as well as drain waters may be because of formation
of hydroxides, complexes or sulphate, carbonate precipitation
which results in decrease of metal concentrations at various
places.

Water Quality of River Jamuna

Without any fear of contradiction it may be stated that
the nature, cause and mode of metal pollution that is observed
in the metropolitan centre of Delhi and its threat to river Jamuna
is a serious health hazards with respect to various metals
observed in the river water.

The total waste discharge of various drains in MT/yr is given in Table B, which reveals that drain waters contribute maximum quantity of trace metals into river water around Delhi. On comparison, it is found that, the metal concentration is higher than due to the natural sources. Upstream of Wazirabad shows the metal concentrations only because of natural sources as this part is free from waste addition because it is not much populated.

Okhala station is considered as the last sampling station because river Jamuna leaves Delhi after Okhala to see the metal pollution due to waste addition from the city.

Table C reveals that the Mn, Zn, Cu and Pb concentration increases from Wazirabad to Okhala, the stretch of river Jamuna around Delhi, however, Ni concentration decreases but Cr and Fe concentration found is same.

Metal contribution from various drains is much higher as predicted from Table C, but overall it is found that the metal concentration is not much higher compared to total waste discharge at Okhala.

This observation proved that the metal ions Cr^{+6}, Fe^{++} and Ni^{++} might have deposited in the bottom sediments of river Jamuna, hence metal concentration observed is lower at Okhala.

However, Mn^{++}, Cu^{++}, Zn^{++} and Pb^{++} concentration is higher than the expected concentration of metals at Okhala. This finding indicates that drains are polluting the river.

Whereas metal concentrations found at Okhala exceed the standard limits for public water supplies (Ni^{++}, Cr^{+6} and Pb^{++}). However, though Zn, Fe, Mn and Cu concentrations are within the permissible limits, deposition of these metals into bottom sediments confirms the pollution in sediments which may be harmful to aquatic plant life, fishes, green algae etc.

From the whole impact of drain waters on river Jamuna, it is concluded that, metals are depositing in the bottom sediments, and are present in good proportion at Okhala. Ni - concentration is particularly hazardous because it induces pulmonary cancer (Simith, 1972) and other nickel compounds may also be carcinogenic. It is normally toxic to plant life also (Patterson, 1971). Cr^{+6} - chromium is hexavalant form which is much more toxic than Cr^{+3}. Smith (1972) discusses the respiratory damage and chromate dermatitis whereas Pb^{++} toxicity affects the three systems, neural, hematopoietic and renal(Goyer et. al., 1972) and lead may interfere specially with nerve-to-muscle transmission causing damage to the brain which may be sufficient to cause edematous swelling. Lead also induces anemia, impairs kidney tubular transport which ultimately causes irreversible

renal insufficiency. Metal retardation can be expected from such exposure, while Zn, Cu, Fe can cause toxicity.

Taking into consideration all these factors, the metal concentration observed in river Jamuna can cause the serious health hazards as the water supply is mainly from this stretch to Delhi people.

The extent of pollution load to the natural water system due to disposal of sewage domestic, industrial and other waste, which is going on would, one day, force the country to confront a situation, when the nation would discover that most of the natural water courses either have reached a stage that they are beyond repair which would always remain beyond the nation's reach.

In such a situation the untreated sewage from upstream city is bound to affect the health of the people of the downstream city because the same river would invariably serve as the source of water supply. To minimise this health risk endangering the analysis of waste water to be added into river Jamuna by various drains in Delhi should be done before mixing to river.

Table A: Average concentration of metals in drain
(in ppm)

S.No.	Name of the drain	Cr^{+6}	Mn^{++}	Fe^{++}	Ni^{++}	Cu^{++}	Zn^{++}	Pb^{++}
1	Najafgarh	0.48	0.017	0.29	0.59	0.038	0.24	0.46
2	Civil Mill	0.40	0.017	0.54	0.58	0.056	0.22	0.36
3	Power House	0.41	0.017	0.39	0.68	0.100	0.20	0.33
4	Barapullah	0.26	0.061	0.27	0.49	0.062	0.22	0.25
	Total	1.55	0.112	1.49	2.34	0.256	0.88	1.40
	Average concentration	0.39	0.028	0.37	0.59	0.064	0.22	0.35

Table B: Total waste discharge of drains (in MT/yr)

S.No.	Name of the drain	Drain discharge (in KLD)	Cr^{+6}	Mn^{++}	Fe^{++}	Ni^{++}	Cu^{++}	Zn^{++}	Pb^{++}
1	Najafgarh	288100	50.48	1.84	30.76	61.78	3.94	25.2375	48.63
2	Civil Mill	5000	0.73	0.032	0.99	1.049	0.102	0.039	0.66
3	Power House	5000	0.74	0.032	0.702	1.231	0.182	0.36	0.59
4	Barapullah	125000	11.63	2.79	12.43	22.24	28.52	10.038	11.41
	Total	423100	63.58	4.694	44.88	86.30	32.74	35.67	61.29

Table C: Average metal concentration in River Jamuna
(in ppm)

S.No.		Cr^{+6}	Mn^{++}	Fe^{++}	Ni^{++}	Cu^{++}	Zn^{++}	Pb^{++}
1	Upstream of Najafgarh drain mixing at Wazirabad	0.40	00	0.36	1.05	0.038	0.16	0.25
2	Average concentration of metals in drains	0.39	0.028	0.37	0.59	0.064	0.22	0.35
3	Weighted discharge of average drains	0.0028	0.0002	0.0026	0.0042	0.0005	0.0016	0.0025
4	Expected concentration of metals if drains are polluting at Okhala	0.4028	0.0002	0.3626	1.0542	0.0385	0.1616	0.2525
5	Observed concentration of metals at Okhala	0.40	0.017	0.36	0.86	0.056	0.17	0.33

73

CHAPTER - V

Conclusion

The River Jamuna flows mainly through recent alluvium and some hard rocks. It also receives several drains, around Delhi, the effect of which, along with the other environmental factors, is, to change the chemical properties of river water. The present work putforward the following conclusions regarding the metal concentration in the river around Delhi.

The study has shown the highest values of chemical constituents compared to world's average river water (Livingstone, 1963).

The primary result obtained from the observations is, high levels of trace metals, including heavy metals can and do exist in certain sewage from domestic and municipal sewage and industrial effluent.

Metal concentrations in drain waters observed are higher than that in river water. It is observed that the metal concentration is lower at Okhala though the waste addition is large in quantity. It indicates that Cr^{+6}, Fe^{++} and Ni^{++} might have deposited in the bottom sediments of river Jamuna.

Mn^{++}, Cu^{++}, Pb^{++} and Zn^{++} pollution is observed due to mixing of drain waters in the river because expected concentration of metals at Okhala is lower than these metal concentrations.

Cr^{+6}, Fe^{++} concentration is same at Wazirabad as well as at Okhala though the drains are polluting the river. Therefore, it seems that natural removal phenomenon is existing in the river water and further study on the natural removal phenomenon is needed.

Ni^{++}, Cr^{+6} and Pb^{++} concentrations in the river at Okhala exceed the standard limits given for public water supplies, however, Zn^{++}, Fe^{++}, Mn^{++} and Cu^{++} concentrations are within the limit of standard values (Table 22).

HCO_3^-, SO_4^{--} and Na^+ concentrations at Wazirabad and K^+ concentration at Barapullah regions, exceed the I.S.I. effluent standard values. Hence accurate analysis of these drains are needed.

Major constituents Na^+ and K^+ are higher at the mixing points of drains into the river, than WHO standard values, however, Ca^{++} and Mg^{++} concentrations are within the limits may be due to different nature of their geological terrain.

To minimise this health risk, not only are the studies necessary to determine, what is the toxic level of each of these metals to approximate public water supplies but analysis of each waste water to be added is required both in the river water as well as at the mixing points, because river water chemistry is changing day by day due to addition of large quantity of waste water into river.

The present investigation is also useful for prediction of different drain water addition to various systems in different natural waters. This study is one of the useful tools for civil as well as chemical engineering. It also helps to improve the knowledge of water quality data for irrigation, industries and domestic purposes.

REFERENCES

Adams, C.E., W. Wesley Ecknefelder and B.L. Goodman (1973):
The effects and removal of heavy metals in biological
treatment. In: Heavy metals in the aquatic environ-
ment. (Krenkel, P.A. ed.), Pergamon Press Ltd.

Agrawal, D.K., Gaur, S.D., Tiwari, I.C., Narayanaswami, N.
and Marwah, S.M. (1976): Physico-chemical characteristics
of Ganges water at Varanasi. Indian Journal Environmentl
Health. Vol. 18, pp 201-206.

Agrawal, Y.K., K.P.S. Raj and M.R. Patel (1978): Metal contents
in the drinking water of Cambay. Water Air Soil Pollution.
Vol. 9, pp 429-431.

Balani, M.C. and H.L. Sarkar (1965): Some observations on the
pollution of river Jamuna at Okhala Water Works. Indian
Journal Environmental Health. Vol. 7, pp 84-86.

Balusu, K.R. and A.K. Sen (1964): Rapid determination of
sulphate in water. Environmental Health. Vol. 6, pp 1-6.

Balusu, K.R. and V.P. Sharma (1966): Survey of Najafgarh
drain downstream of industrial area. Indian Journal
Environmental Health. Vol. 8, pp 103-111.

Beck, K.C. J.H. Reuter and E.M. Perdue (1974): Organic and
inorganic geochemistry of some coastal plain rivers of
the Southeastern United States. Geochim., Cosmochim.
Acta., Vol. 38, pp 341-364.

Berner, R.A. (1971): Chemical Sedimentology. McGraw Hill Publi-
cations. New York. pp 240.

Bewers, J.M., Ian D. Maccaulay and B. Sundby (1974): Trace
Metals in the waters of Gulf of St. Lawrence. Canadian
J. Earth Sciences. Vol. 11, pp 939-950.

Biyani, A.K. (1979): Geochemistry of ground water in and around Delhi. M.Phil. dissertation submitted to J.N.U., New Delhi.

Bloom, H. and A.M. Ayling (1977): Heavy metals in the Derwent Estuary. Environmental Geology. Vol. 2; pp 3-22.

Blutstein, H. and David Smith (1978): Distribution of species of Cu, Pb, Zn and Cd in a water profile of Yerra river estuary. Water Research. Vol. 12, pp 101-112.

Brown, V.M., T.L. Shaw and D.G. Shurben (1974): Aspects of water quality and toxicity of copper to rainbow trout. Water Research. Vol. 8, pp 797-803.

Brown, J., N.J. Ray and M. Ball (1976): The disposal of pulvarized fuel ash in water supply catchment areas. Water Research. Vol. 10, pp 1115-1121.

Brugmann, L. (1977): Occurrence and analysis methods of trace metal forms in water. Hydrochim., hydrobiol. Vol. 5, pp 421-429.

Burell, D.C. (1975): Atomic Spectrometric Analysis of heavy metal pollutants in water. Ann Arbor; Ann Arbor Science, Michigan.

Charles, C. and Neil, F.S. (1972): Trace elements in bottom sediments from upper Peoria lake, middle Illinois river - A pilot project. Environmental Geology Notes, No. 56, pp 1-21.

Ciaccio, L.L. (1972): Water and water pollution Hand Book. Vol. 3, Marcell Dekker, Inc. New York.

Clubb, R.W., A.R. Gaufin and J.L. Lords (1975): Acute cadmium toxicity studies upon nine species of aquatic insects. Environmental Research. Vol. 9, pp 332-341.

Cook, J. (1977): Environmental pollution by heavy metals. International J. Environmental Studies. Vol. 9, pp 253-266.

CSMRS (1973): Chemical composition of river waters of India. Cent. Soil Water. Res. Stn., New Delhi.

CWPCB (1979): Control of urban pollution series. Cups/1/. Union Territory of Delhi. Cent. Water Pollution Control Board., New Delhi.

Dalavi, R.A. (1978): Thermodynamic approach to the water-mineral equilibria in the Jamuna river basin. M.Phil. dissertation submitted to JNU, New Delhi.

Davis and De Weist (1967): Hydrogeology. John Willey Internationals. pp 463.

Davis, J.A. and J.O. Leekie(1978): Effect of adsorbed complexing ligands on trace metal uptake by hydrous oxides. Environmental Sc. Techno. Vol. 12, pp 1309-1315.

Devey, D.G. (1973): The significance of man-made source of phosphorous, detergents and sewage. Water Research. Vol. 7, pp 35-44.

Duce R.A., J.G. Quinn, C.E. Onley, S.R. Piotrowicz, B.J. Ray and T.L. Wade (1972): Enrichment of heavy metals and organic compounds in the surface microlayer of Narraganselt Bay. Rhode Island. Science. Vol. 176, pp 161.

Duchart, P., S.E. Calvert and N.B. Price (1973): Distribution of trace metals in the pore waters of shallow water marine sediments. Limnology and Oceanography. Vol. 18, pp 605-610.

Durum, W.H. (1974): Occurrence of some trace metals in surface and ground water. Univ. Illinois. Urbana Champaign. III Water Quality Conference Proc. Vol. 16, pp 17-25.

Durum, W.H. and Haffty, J. (1963): Implications of the minor element content of some major streams of the world. Geochim., Cosmochim. Acta. 27:1.

Durum, W.H., J.D. Hem and S.G. Heidel (1971): Reconnaissance of selected minor elements in surface waters of the United States. Circular 643. (Washington D.C., U.S. Geol. Survey).

Eckenfelder and Hood (1950): A critical evaluation of routine sewage analysis. Water and Sewage Works. Vol. 97, pp 138-141.

Eckenfelder and Hood (1950): Alkalinity significance in sewage. Water and Sewage Works. Vol. 97, pp 189-193.

Eckenfelder and Hood (1950): Alkalinity nitrogen relationship in sewage treatment. Water and Sewage Works. Vol. 97, pp 507-510.

Edwards, A.M.C. (1973): The variation of dissolved constituents with discharge in some Norfolk rivers. J. of Hydrology. Vol. 18, pp 219-242.

Elder, J.F. (1975): Complexation side reactions involving trace metals in natural water systems. Limnol. Oceanogr. Vol. 20, pp 96-102.

Florence, T.M. (1977): Trace metal species in fresh waters. Water Research, Vol. 11, pp 681-687.

Fonselius Stig, H. (1970): Some trace metal analysis in the mediterranean, the Red Sea, and Arabian Sea. Bull. Instt. Oceanogr. Monaco. Vol. 69, pp 1-15.

Francis, K.V. and Richard, K. (1974): Environment and Pollutions. Charles C. Thomas. Publisher. Springfield, Illinois, USA.

Garrels, R.M. and C.L. Christ (1965): Solutions, minerals and equilibria. Harper and Row, New York.

Ghose, M.K. (1978): Chemical analysis of trace metals in Raw-sewage and treated effluents. Indian J. Environmental Health. Vol. 20, pp 354-358.

Gibbs, R.J. (1967): Geochemistry of Amazon river. Bull. Geo. Soc. America. Vol. 78, pp 1203-1212.

Gibbs, R.J. (1970): Mechanisms controlling world water chemistry. Science. Vol. 170, pp 1089-1090.

Gibbs, R.J. (1972): Water chemistry of Amazon river. Geo. Chim. Cos. Acta., Vol. 36, pp 785-789.

Gibbs, R.J. (1973): Mechanism of metal transport in rivers. Science. Vol. 180, pp 71-73.

Giddings, C.J. and Monroe (1972): Our chemical environment. San Francisco, Canfield Press.

Giesy, J.P., L.A. Briese and Gordon J. Leversee (1978): Metal binding capacity of selected marine surface waters. Environmental Geology. Vol. 2, pp 257-268.

Gloss, G.E. (1977): Identification and distribution of inorganic components in water: What to measure? Ann N.Y. Acade, Sc. Vol. 298, pp 31-36.

Gloyana, E.F., Y.A. Yusuf and T.J. Padden (1971): Non equilibrium systems in natural water chemistry. In: Advances in chemistry series. Vol. 106. (Washington D.C., American Chemical Society).

Golterman, H.L. (1971): Methods for chemical analysis of fresh water. J.B.P. Hand Book. No. 8.

Goyer, R.A. and J.J. Chislom (1972): Lead in metallic contaminants and human health. (D.H.K. Lee, ed.), Aca. Press. New York. pp 69.

Grieve, O.A. (1976): Heavy metals in detaic sediments of the Fraser River, British Columbia. Can. J. Earth Sc. Vol.13, pp 1683-1693.

Grieve, D. and K. Fletcher (1977): Interactions between Zn and suspended sediments in the Fraser river estuary. British Columbia. Estuarine and Coastal Marine Science. Vol. 5, pp 415-419.

Groof, D.E.A.J. (1975): Field observations on the transport of heavy metals in sediments. In: Heavy metals in the aquatic environment. (Krenkel, P.A. ed.), Pergamon Press Ltd.

Grove, A.T. (1972): The dissolved and solid load carried by some African rivers. J. Hydrology. Vol. 16, pp 277-300.

GWPB (1971-76): Chemical composition of river Jamuna, Chambal and Ganga. Ganga Water Project Basin, New Delhi.

Handa, B.K. (1972): Geochemistry of the Ganga river water. Indian Geohydrology. Vol. 13, pp 71-78.

Harfung, R. (1973): Biological effects of heavy metal pollutants in water. Advan. Exp. Med. Biol., Vol. 40, pp 161-172.

Henrikson, A. and Balmer, K. (1977): Sampling, preservation and storage of water samples for analysis of heavy metals. Environmental Health. Vol. 2, pp 33-38.

Henrikson, A. and R.F. Wright (1978): Concentration of heavy metals in small Norwegian Lakes. Water Research. Vol.12, pp 101-112.

Herbert, A.L. (1975): Analytical techniques forhheavy metals other than mercury. In: Heavy metal in the aquatic environment. (Krenkel, P.A. ed.). Pergamon Press Ltd.

Huggett, R.J. (1973): Utilizing metal concentration relationship in the eastern oyster to detect heavy metal pollution. Water Research. Vol. 7, pp 451-456.

I.S.I. (1979): Tolerance limits for inland surface water, public water supplies and effluents subject to pollution. Indian Standard Institution, New Delhi.

Jenkins, D, J.F. Furguson and A.B. Menar (1971): Chemical processes for phosphates removal. Water Research. Vol. 5, pp 369-389.

Jenne, E.A. (1968): Controls on Mn, Fe, Co, Ni, Cu and Zn concentrations in soils and water: The significant role of hydrous Mn and Fe oxides. Advan. Chem. Ser. Vol. 73, pp 337-388.

Jennett, J.C. and J.L. Foil (1979): Trace metal transport from mining, milling and smelting water sheds. Water Pollution Control Federation. Vol. 51, pp 378-404.

Kaushik, N.K. and D. Prasad (1964): Coliform periodicity in water of river Jamuna at Wazirabad, Delhi. Environmental Health. Vol. 6, pp 118-124.

Khan, M.A.Q. and Bederka, J.P. (1974): Survival in toxic
environments. Acad. Press, Inc. New York.

Klien, L. (1957): Aspects of river pollution. Butterwarths.
London.

Klien, L. (1977): River Pollution. Chemical effects and
control. Butterwarths. London.

Krauskopf, K.B. (1956): Factors controlling the concentration
of thirteen rare metals in sea waters. Geochim. Cosmo-
chim. Acta. Vol. 9:1.

Krauskopf (1967): Introduction to Geochemistry. McGraw Hill
Col, Kogakusho Tokyo, Japan.

Krenkel, P.A. (1975): Heavy metals in the aquatic environment.
An international conference: A supplement to progress in
water technology. Pergamon Press Ltd.

Kronfeld, J. and J. Navrot (1975): Aspects of trace metal
contamination in the coastal rivers of Israel. Water,
Air and Soil Pollution. Vol. 4, pp 127-134.

Kubota, J., E.L. Mills and R.T. Oglesby (1974): Pb, Cd, Zn,
Ca and Co in streams and lake waters of Cayuga Lake basin,
New York. Environ. Sc. Technology. Vol. 8, pp 243-248.

Kundra, R., J.L. Nagpal, S.R. Verma and S.K. Shrivastava (1977):
Raw water quality at Wazirabad and Okhala reservoirs in
Delhi. Indian J. Environmental Health. Vol. 19, pp 329-339.

Lee, G.F. (1975): Role of hydrous metal oxides in the transport
of heavy metals in the environment. In: Heavy metals
in the aquatic environment (Krenkel, P.A. ed.), Pergamon
Press Ltd.

Lewin, V.H. (1973): Phosphate in sewage and sewage treatment.
Water Research. Vol. 7, pp 55-67.

Livingstone, D. (1963): Chemical compositions of rivers
and lakes of the world. U.S. Geol. Survey: Prof. Pap.,
440G, pp 64.

Loring, D.H. (1975): Hg in the sediments of Gulf of St. Lawrence.
Canadian J. Earth Sc. Vol. 12, pp 1219-1237.

Loring, D.H. (1976): Distribution and partition of Zn, Cu and
Pb in the sediments of the Saguaney Fjord. Can. J.
Earth Sc., Vol. 13, pp 960-971.

Loring, D.H. (1976): Distribution and partition of Co, Ni, Cr
and V in sediments of the Sorfjord Saguaney. Can. J.
Earth Sc., Vol. 13, pp 1706-1718.

Loring, D.H. and D.J.F. Nota (1968): Occurance and significance
of Fe, Mn and Ti in glacial marine sediments from the
estuary of St. Lawrence. J. Fish. Research Board, Can.
Vol. 25, pp 2327-2347.

Loring, D.H. and D.J.G. Nota (1973): Morphology and sediments
of the Gulf of St. Lawrence. Fish. Res. Board. Can. Bull.
182, pp 147.

Mancy, McClelland and Pohland (1974): Applied chemistry of
waste water treatment: Programmed learning. Unit VIII,
Applications: pH and alkalinity. An Arbor Science Publi-
shers Inc. Michigan.

Mancy, McClelland and Pohland (1974): Applied Chemistry of
waste water treatment: Programmed learning. Unit VII,
Applications: Inorganic Pollutants. An Arbor Science,
Publishers Inc. Michigan.

Manning, P.G. and S. Ramamoorthy (1973): Equilibrium studies of
metal ion complexes of interest to natural waters, VII:
Mixed ligand complexes of Ca II, involving filvic acid as
a primary ligand. J. Inorg. Nuclear Chem. Vol.35, pp 1577-
1581.

Mc Cardy, J.K. and G.A. Chapman (1979): Determination of
Cu complexing capacity of natural river water, well
water and artificially reconstituted water. Water Research.
Vol. 13, pp 143-150.

Mc Kee, J.E. and H.W. Wolf (1963): Water quality criteria:
California State Res. Cent. Board, Pub. No. 3-A, pp 548.

Merrit, W.F. (1975): Variations in trace element concentrations
along the length of Ottawa river. Can. J. Earth Sci.
Vol. 12, pp 850-857.

Metcalf and Eddy (1979): Waste water engineering treatment.
Tata McGraw Hill Publishing Col Ltd., New Delhi.

O'Corner, J.T. and C.E. Renn (1964): Soluble-adsorbed zinc
equilibrium in natural waters. J. Amer. WaterWWorks Assoc.
Vol. 56, pp 1055.

O'Corner, J.T., C.E. Renn and I. Winter (1964): Zn concentration
in rivers of the kgChesapeake Bay Region. J. Amer. Water
Works Assoc. Vol. 56, pp 280.

Olania, M.S., K.L. Saxena and H.C. Sharma (1976): Pollution
studies of Chambal river and its tributaries at Kota.
Indian J. Environmental Health. Vol. 18, pp219-226.

Oliver, B.G. (1973): Heavy metal levels in Ottawa and Rideau
river sediments. Envi. Sc. Technology. Vol. 7, pp 135-137.

O'Shea, T.A. and K.H. Mancy (1978): The effect of pH and
hardness metal ions on the competitive interactions between
trace metal ions and inorganic and organic complexing agents
found in natural waters. Water Research Vol. 12, pp 703-711.

Paliwal, K.V. and B.R. Yadav (1976): Irrigation water quality and crop management in the Union Territory of Delhi. Water Technology Centre. I.A.R.I., New Delhi.

Patterson, J.B.E. (1971): Metal toxicities arising from industry. In: Trace elements in soils and crops. Technical Bull. 24., Ministry of Agriculture, Fisheries and Food. London, pp 193.

Patterson, J.W. (1975): Physical-chemical methods of heavy metals removal. In: Heavy metals in the aquatic environment (Krenkel, P.A. ed.) Pergamon Press Ltd.

Paul, M. New Berne (1976): Trace substances and Health. A Hand Book. Part I, Marcel Dekker Inc. New York.

Pitwell, L.R. (1974): Metals coordinated by ligans normally found in natural waters. J. Hydrology. Vol. 21, pp 301-404.

Ramamoorthy, S. and D.J. Kushner (1975): Heavy metal binding sites in river water. Nature. Vol. 256, pp 399-401.

Ramamoorthy, S. and D.J. Kushner (1975): Heavy metal binding components of river water. J. Fish. Res. Board, Canada. Vol. 32, pp 1755-1766.

Rao, K.L. (1975): India's Water Wealth. Oxford University Press, New Delhi.

Reeder, S.W. Brain, H and A.A. Levinson (1972): Hydrogeochemistry of surface waters of the Mackenzie river drainage basin. Canada. I: Factors controlling inorganic composition. Geochim. Cosmochim Acta. Vol. 36, pp 825-865.

Rubin, A.J. (ed.) (1974): Aqueous environmental chemistry of metals. An Arbar Science Publication. An arbour. Michigan. pp 77-172.

Sandhu, S.S., Warren and Nelson (1978): Trace inorganics
in rural potable water and their correlation to possible
sources. Water Research. Vol. 12, pp 257-261.

Schroeder, D.C. (1974): Potential transformation of chromium
in natural waters. Water, Air and Pollution. Vol. 3,
pp 354-365.

Shapiro, M.A. (1975): Investigations of heavy metals and other
persistent chemicals, Westernport Bay, Australia. In:
Heavy metals in the aquatic environment (Krenkel, P.A.ed.)
Pergamon Press Ltd.

Shimp, N.F., Harry, V., Leland, W.A. White (1970): Distribution
of major, minor and trace constituents in unconsolidated
sediments from Southern Lake, Michigan. Environmental
Geology Notes. No. 32, pp 1-19.

Shrivastava, S.K. and N.K. Kaushik (1966): Certain aspects of
pollution and purification in Agra canal. Environmental
Health. Vol. 8, pp 123-133.

Shuman, M.S., C.L. Haynie, C.L. and Smock, L.A. (1978): Modes
of metal transport above and below waste discharge on the
Haw river. Environmental Sc. Techno. Vol. 12, pp 1066-1069.

Silvey, W.D. (1967): Occurrence of selected minor elements in
the waters of California. Water Supply Paper. 1535-L.
(Washington D.C., U.S. Geological Survey).

Singer, P.C. (1973): Trace metals and metal organic interactions
in natural waters. An arbor Sc. Publishers Inc. An arbor.
Michigan.

Skei, J.M., N.B. Price and S.E. Calvert (1972): Distribution
of heavy metals in the sediments Sorfjord Norway. Water, Air
and/Pollution. Vol. 1, pp 452-461.
       Soil

Smith, R.G. (1972): Five of potential significance.
In: Metallic contaminants and human health.
(D.H.K. Lee, ed.) Aca. Press, New York. pp 139-149.

Spencer, D.W. and E.T. Degens (1968): Factors affecting
element distributions in sediments. In: Origin and
distribution of the elements. (L.H. Arhens, ed.) Int.
Series Monographs, in Earth Sciences, Pergamon Press
Ltd. pp 901-998.

Stiff, M.J. (1971): The chemical status of copper in polluted
fresh water and a scheme of analysis to differentiate
them. Water Research. Vol. 5, pp 585-599.

Stum, W. and J. Morgan (1974): Aquatic Chemistry. Widely-
Intersciences, New York.

Subramanian, V. (1974): Water Chemistry of St. Lawrence.
Marit. Sediment. Vol. 10, pp 97-105.

Subramanian, V. (1978): Input by Indian rivers into world
oceans. Proc. Indian Acad. Sc. Vol. 87, pp 77-88.

Subramanian, V. (1979): Chemical and suspended sediment cha-
racteristics of rivers of India. J. Hydrology, Vol. 44,
pp 37-55.

Subramanian, V. and de Anglejan (1976): Water Chemistry of St.
Lawrence Estuary. J. Hydrology. Vol. 29, pp 341-354.

Subramanian, V. and others (1976): Factors affecting the
concentrations of Fe, Mn, Ni in natural waters. National
Symposium on Hydrological Problems Related to the Deve-
lopment of Power and Industries, IIT Kanpur.

Sylva, R.N. (1976): The Environmental Chemistry of Cu II. Water
Research. Vol. 10, pp 789-792.

Taylor, J.H. (1975): Enrichment of Zn, Pb and Cu in recent sediments of Windermere, England. Environ. Sc. Techno. Vol. 13, pp 693-697.

Toda, F, H. Oda, H. Tochikawa and S. Suzuki (1978): Distribution of heavy metals in the bottom mud of upper river in Japan. J. Hyg. Chem. (Tokyo). Vol. 24, pp 65-70.

Turekian, K.K., R.C. Harris and D.G. Gohnson (1967): The variations of Si, Cl, Na, Ca, Sr, Ba, Co and Ag in the Neuse river, North Carolina. Limnol. Ocean. Vol. 12, pp 702.

Vogel, A.I. (1975): A text book of inorganic analysis ELBS and Longman. Lowe and Brydone (Printers) Ltd., Thetford, Norfolk.

Wadia, D.N. (1978): Geology of India. Tata McGraw Hill Pub. Co.

Warts, H. (1953): The significance for algae of chelating substances in the nutrient solutions. Physiol. Plant Vol. 6, pp 538-543.

Wedepohl, K.H. (1970): Hand book of Geochemistry, Vol. 1-4, Springer and Verlag, Berlin.

Webber, W.J. and H.S. Posslet (1974): Equilibrium models and precipitation reactions for Cd II. In: (Rubin, A.J. ed.) Aqueous environmental chemistry of metals. An arbor Sc. An arbor. Michigan.

Whitfield, P.H. and A.G. Lewis (1976): Control of
    biological availability of trace metals to a colanoid
    copepod in a coastal fjord. Estuarine Coastal Marine
    Sc. Vol. 4, pp 255-266.

Wood, J.M. (1973): Metabolic cycles for toxic element in the
    environment. In: Heavy metals in the aquatic environ-
    ment. (Krenkel, P.A. ed.) Pergamon Press Ltd.

Yeats, P.A. and J.M. Bewers (1976): Trace metals in the waters
    of the Saguenay Fjord. Can. J. Earth Sc. Vol. 13, pp 1319-
    1327.

Zitko, P., W.V. Carson and W.G. Carson (1973): Prediction of
    incipient lethal levels of copper to juvenile Atlantic
    Salmon in the presence of humic acid by cupric electrode.
    Env. Cont. Tox. Bull. Vol- 10, pp 265-271.

APPENDIX

Table 1: TSM in ppm

Stations	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	17.21	153.85	780.82	12.35
	R	2	1325.76	50.62	466.67	6.94
	R	3	5765.62	126.51	25.31	23.08
Civil Mill	R	4	-	69.77	24.39	8.70
	D	5	634.15	147.24	383.72	304.73
Power House	R	6	1723.68	144.74	741.57	942.20
	D	7	2558.13	119.56	652.17	12.58
	R	8	688.52	2000	289.16	628.83
	R	9	4593.75	861.11	36.81	48.82
Barapullah	R	10	2698.41	136.98	36.58	117.18
	D	11	22.47	1319.45	24.69	106.07
	R	12	3131.58	1455.88	40.82	34.45
	R	13	3051.28	1723.68	129.50	571.03
Okhala	R	14	2573.52	1024.39	100.25	18.54
	R	15	695.12	824.58	55.56	22.42

D = Drain water

R = River water

Table 2

Temperature in °C

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	22	30	32	28
	R	2	20	30	32	28
	R	3	19	30.5	30	28.5
Civil Mill	R	4	-	30.5	30	29
	D	5	22	29.5	32	29
Power House	R	6	20	29.5	32	32
	D	7	21	29	31	34
	R	8	22	31	31	31
	R	9	18	29	32	30
Barapullah	R	10	19	29	32.5	32
	D	11	21	31.5	34	33
	R	12	27	31	32	31.5
	R	13	27	32	32	31
Okhala	R	14	20	33	31	30.5
	R	15	22	30	29	30

Table 3

Conductivity in milli. mhos/cm

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	1.2	0.67	1.60	1.45
	R	2	1.15	0.41	0.49	0.64
Civil Mill	R	3	0.35	0.69	0.38	0.40
	R	4	-	0.53	0.52	0.55
	D	5	1.30	1.15	1.15	0.96
Power House	R	6	0.40	0.56	0.47	0.57
	D	7	1.15	1.20	1.15	0.66
	R	8	0.74	0.71	0.61	0.93
	R	9	0.39	0.54	0.48	0.57
Barapullah	R	10	0.38	0.53	0.51	0.56
	D	11	1.90	2.10	2.05	1.80
	R	12	1.55	0.69	0.50	0.68
	R	13	0.45	0.75	0.47	0.62
Okhala	R	14	0.46	0.58	0.65	0.56
	R	15	0.62	0.65	0.58	0.61

Table 4

pH

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	8.85	7.70	7.10	6.81
	R	2	7.20	8.30	7.70	7.19
	R	3	8.10	7.75	8.00	8.01
Civil Mill	R	4	...	8.10	7.30	7.18
	D	5	7.50	7.45	7.00	6.77
Power House	R	6	7.90	7.35	7.10	7.23
	D	7	7.50	7.65	7.40	7.26
	R	8	7.65	7.30	7.00	6.81
	R	9	8.00	7.75	7.35	7.15
Barapullah	R	10	8.35	7.65	7.50	7.35
	D	11	7.90	7.70	8.10	7.30
	R	12	8.10	8.00	7.45	7.36
	R	13	8.20	7.90	7.40	7.40
Okhala	R	14	8.10	7.95	7.70	7.74
	R	15	7.40	7.80	7.80	7.40

Table 5

Total Alkalinity in ppm.

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	690.483	174.08	734.272	400.752
	R	2	507.073	130.521	275.352	222.64
	R	3	291.297	141.398	229.46	178.112
Civil Mill	R	4	-	130.521	229.46	178.112
	D	5	873.892	228.412	367.136	311.584
Power House	R	6	496.284	119.644	150.352	133.524
	D	7	787.582	250.166	275.352	222.64
	R	8	463.918	163.152	229.462	133.524
	R	9	291.297	130.521	229.462	267.168
Barapullah	R	10	280.508	130.521	275.352	267.168
	D	11	1197.556	413.318	642.488	1113.20
	R	12	1014.147	152.275	183.568	222.64
	R	13	345.241	152.275	229.46	178.112
Okhla	R	14	334.452	130.521	413.08	178.112
	R	15	442.341	152.275	229.46	156.312

Table 6

Chloride Concentration in ppm.

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	160.50	158.77	159.30	159.30
	R	2	141.60	59.90	48.03	56.64
	R	3	20.03	18.97	15.29	22.37
Civil Mill	R	4	-	38.94	24.78	50.69
	D	5	108.53	97.91	84.51	87.29
Power House	R	6	21.45	39.29	24.78	55.43
	D	7	97.91	82.55	86.09	60.18
	R	8	53.10	51.89	38.94	92.04
	R	9	23.57	46.02	24.78	51.81
Barapullah	R	10	18.83	43.61	28.32	50.69
	D	11	102.66	235.97	221.81	251.340
	R	12	179.33	55.43	27.11	70.40
	R	13	27.16	60.18	27.11	56.64
Okhala	R	14	31.36	31.86	35.40	50.48
	R	15	54.32	41.27	28.32	43.61

Table 7

Sulphate Concentration in ppm.

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	360	180	1060	1160
	R	2	1360	1280	1400	1160
	R	3	1240	1240	1440	1060
Civil Mill	R	4	-	1240	1120	1360
	D	5	1200	400	740	1080
Power House	R	6	1320	1160	520	1160
	D	7	1840	860	1200	1400
	R	8	1540	440	280	780
	R	9	1660	360	1080	1320
Barapullah	R	10	1360	980	780	1160
	D	11	1160	1160	940	1520
	R	12	1160	860	940	1400
	R	13	1160	1360	1240	1980
Okhla	R	14	1240	1480	1400	220
	R	15	1120	1400	1280	1560

Table 8

Phosphate Concentration in ppm.

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	0.01	0.60	0.15	0.10
	R	2	0.31	0.70	0.05	0.10
	R	3	0.015	1.10	0.10	0.10
Civil Mill	R	4	-	1.00	0.10	0.10
	D	5	0.35	4.85	0.10	1.65
Power House	R	6	0.25	0.45	0.15	0.02
	D	7	4.85	3.50	0.07	0.05
	R	8	2.68	1.90	0.05	0.10
	R	9	0.50	0.90	0.10	0.00
Barapullah	R	10	0.40	0.50	0.07	0.05
	D	11	1.80	0.15	0.10	0.10
	R	12	1.80	0.15	0.06	0.03
	R	13	0.50	0.10	0.10	0.00
Okhala	R	14	0.85	1.15	0.10	0.025
	R	15	1.60	0.07	0.10	0.025

Table 9

Silicate Concentration in ppm.

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	11	9	13	13
	R	2	12	18	8	9
	R	3	11	4	12	8
Civil Mill	R	4	-	6	9	9
	D	5	14	10	13	10
Power House	R	6	13	11	14	10
	D	7	17	8	13	11
	R	8	14	8	10	13
	R	9	7	4	10	5
Barapullah	R	10	7	3	13	6
	D	11	21	10	17	10
	R	12	26	4	10	6
	R	13	10	5	10	5
Okhala	R	14	9	18	9.1	14
	R	15	9	7	9	5

Table 10

Sodium Concentration in ppm.

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	185	49.5	56	211.5
	R	2	141	35.5	24	46
	R	3	34	28	17	26
Civil Mill	R	4	-	37	30.5	40
	D	5	194	65.5	55	58
Power House	R	6	42.5	45	25.5	43
	D	7	130	63	59	48.5
	R	8	82.5	46	33.5	56
	R	9	40	41	27	42
Barapullah	D	10	38.5	41	26	40
	D	11	255	142	138	189
	R	12	205	48	27	48.5
	R	13	47	45	28	44
Okhala	R	14	63	40	37	42.5
	R	15	77	44	33	44

Table 11

Potassium Concentration in ppm.

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	8	9	17.5	33.5
	R	2	14.5	4	4	7.5
	R	3	4	8	2	2.5
Civil Mill	R	4	—	8	4	6
	D	5	4.5	35	31	28
Power House	R	6	5	7	3	6
	D	7	40	35	33.5	22
	R	8	22	16	10	27
	R	9	4	10	4	7
Barapullah	R	10	4	7	4	7
	D	11	26	35	29	28
	R	12	21	8	5	9
	R	13	5	10	8	8
Okhala	R	14	6	7	12	8
	R	15	10	20	25	9

Table 12

Magnesium Concentration in ppm.

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	5.4	4.6	3.8	4.3
	R	2	4.3	3.1	1.4	2.8
	R	3	3.15	4.3	1.6	2.1
Civil Mill	R	4	-	4.	1.2	2.0
	D	5	5.65	4.9	2.2	2.3
Power House	R	6	3.3	3.4	1.5	2.4
	D	7	3.3	4.7	2.3	2.65
	R	8	3.7	3.15	1.6	2.8
	R	9	2.9	4	1.1	2.8
Barapullah	R	10	2.67	3.4	2.65	3.3
	D	11	7.2	5.5	5.4	1.3
	R	12	6.35	3.9	1.9	3.4
	R	13	2.9	4.8	2.2	3.15
Okhala	R	14	3.75	3.8	2.5	1.7
	R	15	2.2	3	1.7	1.7

Table 13

Calcium Concentration in ppm.

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	31	55	63	51
	R	2	32	52	45	47
	R	3	35	58	43	41
Civil Mill	R	4	-	50	46	45
	D	5	39	62	55	53
Power House	R	6	36	49	45	45
	D	7	54	56	59	50
	R	8	41	55	48	52
	R	9	44	52	49	45
Barapullah	R	10	40	51	45	47
	D	11	59	45	42	42
	R	12	29	55	45.5	51
	R	13	41	57	42	50
Okhala	R	14	38	53	50	47
	R	15	48	55	46	49

Table 14

Chromium Concentration in ppm.

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	0.30	0.30	0.57	0.75
	R	2	0.44	0.44	0.30	0.30
	R	3	0.30	0.30	0.44	0.57
Civil Mill	R	4	-	0.44	0.14	0.30
	D	5	0.44	0.57	0.30	0.30
Power House	R	6	0.30	0.30	0.30	0.14
	D	7	0.30	0.30	0.57	0.44
	R	8	0.14	0.14	0.30	0.44
	R	9	0.14	0.14	0.14	0.30
Barapullah	R	10	0.14	0.14	0.57	0.44
	D	11	0.14	0.14	0.44	0.30
	R	12	0.30	0.30	0.30	0.30
	R	13	0.14	0.57	0.30	0.30
Okhala	R	14	0.44	0.30	0.57	0.30
	R	15	0.57	0.57	0.14	0.30

Table 15

Manganese Concentration in ppm.

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	0.00	0.07	0.00	0.00
	R	2	0.00	0.00	0.00	0.00
	R	3	0.00	0.00	0.00	0.00
Civil Mill	R	4	0.00	0.00	0.00	0.00
	D	5	0.00	0.00	0.07	0.00
Power House	R	6	0.00	0.00	0.07	0.00
	D	7	0.00	0.00	0.07	0.00
	R	8	0.00	0.00	0.17	0.00
	R	9	0.00	0.00	0.17	0.07
Barapullah	R	10	0.00	0.00	0.07	0.00
	D	11	0.075	0.17	0.00	0.00
	R	12	0.17	0.07	0.00	0.00
	R	13	0.00	0.00	0.00	0.00
Okhala	R	14	0.07	0.00	0.00	0.00
	R	15	0.00	0.00	0.00	0.00

Table 16

Iron Concentration in ppm.

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	0.25	0.25	0.42	0.25
	R	2	0.25	0.12	0.22	0.25
	R	3	0.47	0.25	0.25	0.47
Civil Mill	R	4	-	0.47	0.47	0.47
	D	5	0.42	0.25	1.25	0.25
Power House	R	6	0.35	0.47	0.47	0.25
	D	7	0.47	0.47	0.25	0.35
	R	8	0.52	0.42	0.47	0.25
	R	9	0.25	0.25	0.47	0.125
Barapullah	R	10	0.12	0.35	0.47	0.25
	D	11	0.42	0.42	0.25	0.25
	R	12	0.25	0.25	0.36	0.41
	R	13	0.25	0.25	0.25	0.25
Okhala	R	14	0.25	0.42	0.42	0.35
	R	15	0.47	0.25	0.25	0.47

Table 17

Nickel Concentration in ppm.

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	0.40	0.40	1.15	0.40
	R	2	0.75	0.75	0.40	0.75
	R	3	1.15	1.15	0.75	1.15
Civil Mill	R	4	–	0.75	0.75	0.40
	D	5	0.40	0.75	0.40	0.75
Power House	R	6	1.15	0.75	0.75	0.75
	D	7	0.75	0.40	0.40	1.15
	R	8	0.40	0.40	0.75	1.15
	R	9	0.75	0.40	0.75	0.40
Barapullah	R	10	0.75	0.75	0.75	0.75
	D	11	0.40	0.40	0.40	0.75
	R	12	0.40	0.40	0.40	1.15
	R	13	1.15	0.75	1.15	0.75
Okhala	R	14	0.75	1.15	1.15	0.40
	R	15	0.75	0.75	1.15	0.40

Table 18

Copper Concentration in ppm.

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	0.075	0.00	0.00	0.075
	R	2	0.075	0.075	0.00	0.10
	R	3	0.00	0.075	0.00	0.075
Civil Mill	R	4	–	0.00	0.00	0.00
	D	5	0.075	0.075	0.00	0.075
Power House	R	6	0.075	0.00	0.175	0.075
	D	7	0.250	0.075	0.00	0.075
	R	8	0.10	0.075	0.07	0.00
	R	9	0.075	0.175	0.00	0.00
Barapullah	R	10	0.075	0.075	0.075	0.075
	D	11	0.00	0.175	0.00	0.075
	R	12	0.075	0.175	0.075	0.00
	R	13	0.00	0.25	0.075	0.00
Okhala	R	14	0.075	0.00	0.075	0.075
	R	15	0.075	0.075	0.00	0.075

Table 19

Zinc Concentration in ppm.

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	0.00	0.52	0.30	0.14
	R	2	0.14	0.14	0.20	0.07
	R	3	0.14	0.14	0.30	0.07
Civil Mill	R	4	-	0.20	0.14	0.07
	D	5	0.30	0.20	0.30	0.07
Power House	R	6	0.14	0.20	0.14	0.07
	D	7	0.37	0.14	0.14	0.14
	R	8	0.20	0.14	0.30	0.07
	R	9	0.30	0.20	0.07	0.07
Barapullah	R	10	0.30	0.14	0.14	0.14
	D	11	0.37	0.30	0.14	0.07
	R	12	0.20	0.30	0.14	0.07
	R	13	0.17	0.37	0.14	0.07
Okhala	R	14	0.37	0.44	0.07	0.07
	R	15	0.37	0.30	0.07	0.00

Table 20

Lead Concentration in ppm.

Station	Sample Nature	Sample Number	24th February 1979	29th March 1979	27th April 1979	24th May 1979
Wazirabad	D	1	0.55	0.50	0.55	0.25
	R	2	0.40	0.40	0.45	0.35
	R	3	0.10	0.25	0.40	0.25
Civil Mill	R	4	-	0.25	0.40	0.82
	D	5	0.40	0.40	0.25	0.40
Power House	R	6	0.40	0.10	0.25	0.25
	D	7	0.40	0.25	0.10	0.55
	R	8	0.25	0.25	0.25	0.40
	R	9	0.25	0.55	0.25	0.25
Barapullah	R	10	0.55	0.55	0.25	0.25
	D	11	0.25	0.25	0.25	0.25
	R	12	0.55	0.10	0.40	0.10
	R	13	0.55	0.55	0.25	0.55
Okhala	R	14	0.10	0.55	0.25	0.40
	R	15	0.10	0.40	0.40	0.25

Table 21: Chemical composition of river Jamuna (Dalavi, 1978)
(in ppm)

No.	Year	pH	SiO_2	Ca	Mg	Na	K	SO_4	HCO_3	Cl
1	Jan. 71	9.0	30	24.08	15.5	1.7	6.25	4.83	129.00	27
2	Feb. 71	9.0	29	39.50	14.5	2.6	5.77	4.77	122.00	43
3	Jan. 72	9.0	37	39.60	10.5	2.0	8.8	5.6	200.00	65
4	Feb. 72	9.0	50	37.80	10.3	2.3	7.25	4.44	153.7	54
5	Jan. 73	8.0	12	30.96	18.58	2.5	6.75	15.14	82.96	98
6	Feb. 73	9.0	16	43.00	27.86	2.3	5.75	12.51	103.70	104
7	Jan. 74	-	18	49.9	18.6	8.3	5.75	12.96	145.2	40
8	Feb. 74	-	21	41.3	23.48	10.00	5.25	16.13	115.9	40
9	Jan. 75	7.5	40	116.9	60.9	45.00	1.00	3.25	145.2	50
10	Feb. 75	8.5	49	91.2	47.5	39.00	1.00	1.40	113.5	48
11	Jan. 76	8.4	36	127.3	116.8	48.00	1.20	1.60	158.6	50
12	Feb. 76	7.2	31	168.6	149.0	19.00	1.00	25.60	156.1	42
*13	Kalanour 77	-	8	44.18	21.55	3.00	1.10	41.60	283.00	15.5
14	Wazirpur 77	-	54	31.29	12.79	12.00	2.20	47.20	363.56	49.6
15	Okhala 77	-	22	34.13	23.60	6.00	0.1	46.4	370.80	49.6

*Chemical composition of Jamuna before Wazirabad at Kalanour.

Table 22: International standards for Public Water Supplies (in ppm)

S.No.	Constituent		WHO 1971	USPHS 1977	ISI 1976	ISI Effluent standards into public sewers
1		TSM	500			Temp. 45°C
		pH	7.0 – 8.5	–	6.0 – 9.0	5.9 – 9.0
2	Total Alkalinity	HCO_3^-	–	250	–	–
3	Chloride	Cl^-	200	250	600	600
4	Sulphate	SO_4^{--}	200	250	–	1000
5	Phosphate	PO_4	0.03 – 0.4	–	–	–
6	Silicate	SiO_2	–	–	–	–
7	Sodium	Na^+	–	–	–	–
8	Potassium	K^+	–	–	–	60.00
9	Magnesium	Mg^{++}	50	–	–	–
10	Calcium	Ca^{++}	75	–	–	–
11	Chromium	Cr^{+6}	0.05	0.05	0.05	2.00
12	Manganese	Mn^{++}	0.10	0.05	–	–
13	Iron	Fe^{++}	0.3	0.3	–	–
14	Nickel	Ni^{++}	–	–	–	2.00
15	Copper	Cu^{++}	1.0	1.0	–	3.00
16	Zinc	Zn^{++}	5.0	5.0	–	15.00
17	Lead	Pb^{++}	0.10	0.05	0.10	1.0

WHO (1971): Environment and Pollutions, Leh and Lak (1974)
USPHS (1977): Natural Water Chemistry (Vol. III).
ISI (1977): Indian Standard Institution (1976).
Effluent Standards (1977): Indian Standard Institution (1976).

Table 23: Pollution Load. Domestic/Industrial Waste Water (CWPCB, 1979)

S.No.	Name of the drains	Area sq. km.		Total Population of drain basin	Flow Domestic	KLD Industrial	BOD Kg/day	No. of industries	Relevant Industries
1	Najafgarh*	153.6	U	14,50,000	270,000	18100	78,000	1956 (ABCD)	A: Textiles including
		678.4	R						dyeing, finishing and dry cleanings.
2	Magazine Road	0.3		2300	400	115	115		
3	Sweeper Colony	0.3		2600	400	-	130		
4	Khyber Pass	0.4		3700	560		485		
5	Metcalf House	1.1		10,300	1200		515		B: Chemical
6	Kudsia Bagh	2.6		23,300	5000		1165		industries including
7	Moat	2.0		18,700	3000		935		fertilizers
8	Trans Yamuna MCD*	9.7	U	104,500	32,000	4300	6725	898 (ABCD)	and pesticides.
9	Mori Gate	39.3 2.6	R	23,300	4000		1165		
10	Civil Mill	3.4		30,400	5000		1520		C: Engineering
11	Power House	3.6		30,200	5000		1510		including
12	Sen Nursing Home*	10.8		92,500	14,000		4625		printing, electroplating etc.
13	No. 14	2.4		20,500	3000		1025		
14	Barapullah*	138		8,28,000	125,000		41400		D: Miscellaneous
15	Maharani Bagh*	8.4		77,700	11,000		3885		industries including
16	Kalkaji*	6.1		56,000	9000	400	3200	475 (ABCD)	ding Soap, food
17	Tughlaqabad	21.5		1,72,000	26000		8600		products, rubber and plastics etc.
	Total	1084.5		29,46,000	537360	154,700	3329		

*Major drains;   U = Urban;   R = Rural

(in Union Territory of Delhi)

1114