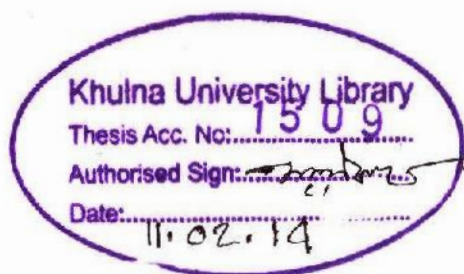


**TRACE METALS IN THE EFFLUENTS AND WATER OF
THE BHAIRAB RIVER AT THE VICINITY OF KHULNA
NEWSPRINT AND HARDBOARD MILLS LTD. KHULNA,
BANGLADESH.**



**Fisheries and Marine Resource Technology Discipline
Khulna University
Khulna-9208
August, 2002**

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By
Examination Roll No. 970614-F
Registration No. 970014
Session- 1996-97

**A Thesis Submitted to the Fisheries and Marine Resources Technology
Discipline in Partial Fulfillment of the Requirements for the Degree of**

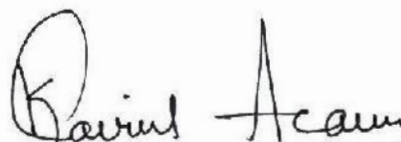
MASTER OF SCIENCE (M.S.)
IN
FISHERIES.



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Approved as to style and content by



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DECLARATION

The results submitted in this thesis are entirely the candidate's own investigations and no part of the results has been accepted for any degree, nor it is being concurrently submitted for any degree.

BY

SUPERVISOR



(MD. YOUSUF MEHEDI)

ASSISTANT PROFESSOR

FISHERIES AND MARINE RESOURCE TECHNOLOGY

DISCIPLINE

KHULNA UNIVERSITY, KHULNA.

ACKNOWLEDGEMENT

The author express his deepest sense of gratitude and sincere appreciation to his respected supervisor Md. Yousuf Mehedi, Assistant Professor in Fisheries and Marine Resource Technology Discipline, Khulna University, Khulna for his constant vigilance, invaluable, erudite, scholastic and constructive guidance for the completion of this research work.

I am very much grateful I convey my heartfelt gratitude to Mrs. Sohela Akhter, Principal Scientific Officer, Chemistry Division, Atomic Energy Center, Dhaka for her constant guidance, constructive suggestion and inspiration throughout the beginning of this work.

The author accords his heartily reverence to Prof. Dr. Md. Saifuddin Shah, Head of Fisheries and Marine Resource Technology Discipline, Khulna University, Khulna for his helpful suggestions and providing all sorts of facilities for the work.

The author is also grateful to Dr. Khairul Azam, Associate Professor, Fisheries and Marine Resource Technology Discipline, Khulna University, Khulna for their co-operation, inspiration and valuable suggestions to carry out this research work successfully.

The author is especially thankful to Dr. S. A. Tarafder, Head, Chemistry Division for his sympathetic permission to work in the laboratory of the Chemistry Division, Atomic Energy Center, Dhaka.

I am indebted to Mrs Shahanara Banu, Scientific Officer, Chemistry Division Atomic Energy Center, Dhaka for constant help and inspiration during the course of this dissertation.

The author also indebted Mr. Dipak Kamal, Assistant Professor, Fisheries and Marine Resource Technology Discipline, Khulna University, Khulna for helping me in the collection of samples and providing me necessary materials.

The author likes to thank Mr. Rezaul Haque, Assistant professor, Fisheries and Marine Resource Technology Discipline, Khulna University, Khulna for collecting literature, constructive advises, reviewing and emendation to dénouement of this research work.

The author is very grateful to all scientists and staffs of the Chemistry Division, Atomic Energy Center, Dhaka for their co-operation and enjoining all divisional facilities to accomplish the work.

The author likes to bestow appreciation to S. M. Moniruzzaman, Md. Mahasin, Mahbub Alam and my classmate's for their heartily help with more propinquity to complete this research work fruitfully.

Lastly, the author likes to be extended thanks Sk. Shaidul Islam and Md Bazlur Rahman for computer composing and data processing.

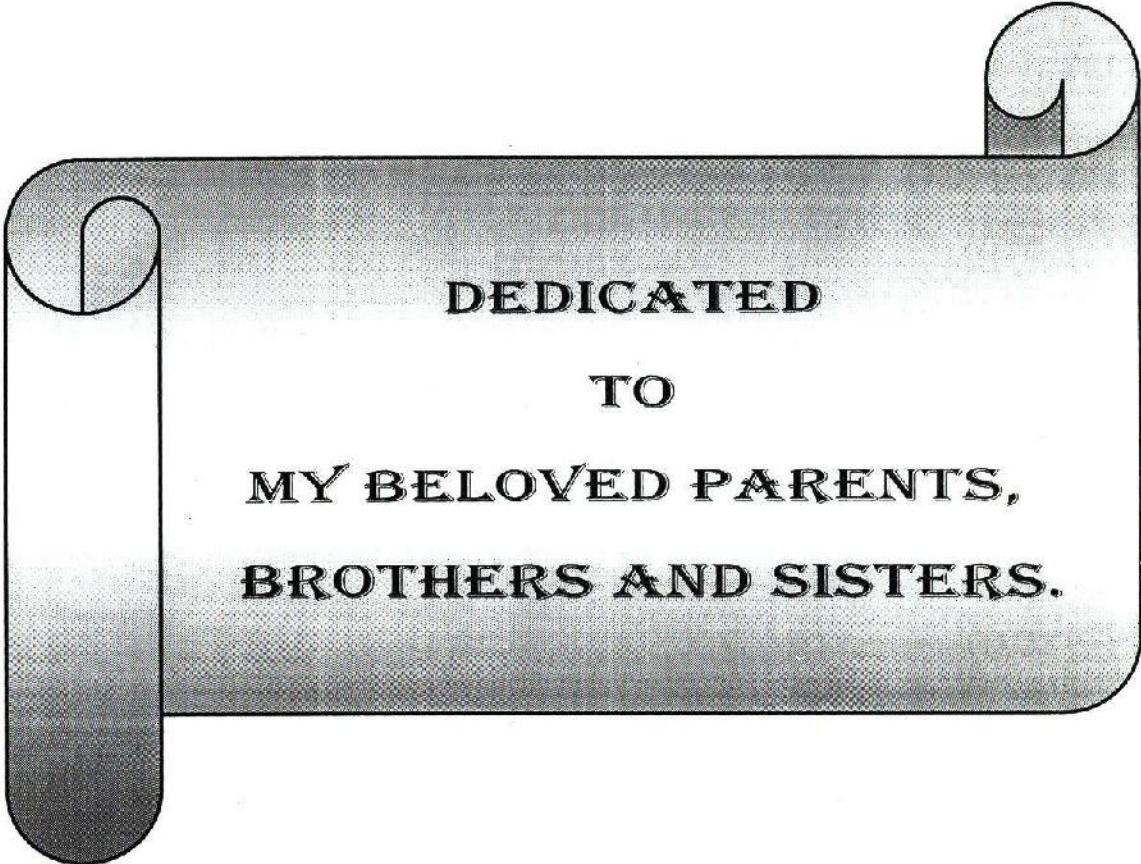
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ABSTRACT

An investigation was carried out to evaluate the status of some trace metals in surface water collected from the Bhairab river at the vicinity of Khulna Newsprint & Hardboard Mills Ltd, Khulna. The samples were analyzed seasonally from December 1998 to November 1999 by employing air acetylene flame in combination with hollow-cathode lamps as well as Atomic Absorption Spectrophotometer (Perkin Elmer Model 3110).

Some physico-chemical parameters of surface water at the studied area were determined simultaneously by standard methods. The maximum and minimum concentrations of Fe, Cu, Cd, Mn, Pb, Cr, Co & Ni were noted in surface water samples as $2756 \mu\text{g.L}^{-1}$ & $62.52 \mu\text{g.L}^{-1}$; $66.14 \mu\text{g.L}^{-1}$ & $2.00 \mu\text{g.L}^{-1}$; $15.52 \mu\text{g.L}^{-1}$ & $<2.08 \mu\text{g.L}^{-1}$; $724 \mu\text{g.L}^{-1}$ & $7.25 \mu\text{g.L}^{-1}$; $70.7 \mu\text{g.L}^{-1}$ & $<5.47 \mu\text{g.L}^{-1}$; $61.3 \mu\text{g.L}^{-1}$ & $<14.7 \mu\text{g.L}^{-1}$; $42.18 \mu\text{g.L}^{-1}$ & $<2.11 \mu\text{g.L}^{-1}$ and $64.74 \mu\text{g.L}^{-1}$ & $<2.46 \mu\text{g.L}^{-1}$ respectively. The maximum and minimum values of physico-chemical parameters of surface water in the studied area *i.e.* Temperature, Hydrogen ion concentration, Electric conductivity, Dissolved oxygen, Bio-chemical oxygen demand, Chemical oxygen demand, Total suspended solids, Total dissolved solids, Total solids, Total alkalinity and Chloride were as 32°C & 24°C ; 7.4 & 6.3; $2400 \mu\text{-mhos.cm}^{-1}$ & $1100 \mu\text{-mhos.cm}^{-1}$; 2.11 mg.L^{-1} & 0 mg.L^{-1} ; 530.4 mg.L^{-1} & 204 mg.L^{-1} ; 3829 mg.L^{-1} & 5 mg.L^{-1} ; 400 mg.L^{-1} & 200 mg.L^{-1} ; 3100 mg.L^{-1} & 200 mg.L^{-1} ; 3300 mg.L^{-1} & 400 mg.L^{-1} ; 88 mg.L^{-1} & 32 mg.L^{-1} ; 125 mg.L^{-1} & 80 mg.L^{-1} respectively. Trace metal concentrations in surface water were observed higher in some stations. The values of physico-chemical parameters in the Bhairab River at the vicinity of the Khulna Newsprint Mills were recorded exceeding the different certified limits with some few exceptions.



**DEDICATED
TO
MY BELOVED PARENTS,
BROTHERS AND SISTERS.**

CONTENTS

	PAGE NO.
ACKNOWLEDGEMENT	IV
ABSTRACT	VI
DEDICATION	VII
LIST OF TABLES	IX
LIST OF FIGURES	X
CHAPTER ONE	
GENERAL INTRODUCTION	1
CHAPTER TWO	
INVESTIGATED AREA AND SAMPLING STRATEGY	9
CHAPTER THREE	
REVIEW OF LITERATURE	12
CHAPTER FOUR	
PHYSICO - CHEMICAL PARAMETERS OF WATER	
4. 1. Introduction	15
4. 2. Materials and Methods	17
4. 3. Results	20
4. 4. Discussion	35
4. 5. Conclusion	43
CHAPTER FIVE	
TRACE METALS IN WATER	
5.1. Introduction	44
5.2. Materials and Methods	46
5.3. Results	50
5.4. Discussion	76
5.5. Conclusion	84
CHAPTER SIX	
REFERENCES	85

LIST OF TABLES

Table No.	Page No.
Table 1 Seasonal variation of some physiochemical parameters in different stations.	28
Table 2 Seasonal variation of trace metal concentrations ($\mu\text{g.L}^{-1}$) in water samples in different stations.	68
Table 3 Seasonal variation of trace metal concentrations at station-1	97
Table 4 Seasonal variation of trace metal concentrations at station-2	98
Table 5 Seasonal variation of trace metal concentrations at station-3	99
Table 6 Seasonal variation of trace metal concentrations at station-4	100
Table 7 Seasonal variation of trace metal concentrations at station-5	101
Table 8 Seasonal variation of trace metal concentrations at station-6	102
Table 9 Seasonal variation of trace metal concentrations at station-7	103
Table 10 Seasonal variation of trace metal concentrations at station-8	104
Table 11 Seasonal variation of trace metal concentrations at station-9	105
Table 12 Seasonal variation of trace metal concentrations at station-10	106
Table 13 Seasonal variation of trace metal concentrations at station-11	107
Table 14 Seasonal variation of trace metal concentrations at station-12	108
Table 15 Seasonal variation of trace metal concentrations at station-13	109
Table 16 Standard concentration calibration for trace metals.	110
Table 17 USPHS (United States Public Health Drinking Water) Water Quality Criteria for Domestic Water Supplies.	110
Table 18 World Health Organization (WHO) Guidelines for Drinking Water Quality.	



LIST OF FIGURES

Figure No.		Page No.
Fig.1	Seasonal variation in water temperature ($^{\circ}\text{C}$) in different stations	29
Fig.2	Seasonal variation in pH in different stations	29
Fig.3	Seasonal variation in electric conductivity ($\text{micro-mhos.cm}^{-1}$) different stations.	30
Fig.4	Seasonal variation in dissolved oxygen (mg/l) in different stations.	30
Fig.5	Seasonal variation in biochemical oxygen demand (mg/l) in different stations.	31
Fig.6	Seasonal variation in chemical oxygen demand (mg/l) in different stations.	31
Fig.7	Seasonal variation in total suspended solids (mg/l) in different stations.	32
Fig.8	Seasonal variation in total dissolved solids (mg/l) in different stations.	32
Fig.9	Seasonal variation in total solids (mg/l) in different stations.	33
Fig.10	Seasonal variation in total alkalinity (mg/l) in different stations.	33
Fig.11	Seasonal variation in chloride (mg/l) in different stations.	34
Fig.12	Flow chart for the detection of trace metal concentrations in water sample by AAS (Atomic Absorption Spectrophotometer).	47
Fig.13	Seasonal variation of the trace metals concentration in surface water sample at station-1	69
Fig.14	Seasonal variation of the trace metals concentration in surface water samples at station-2	69
Fig.15	Seasonal variation of the trace metals concentration in surface water sample at station-3	70
Fig.16	Seasonal variation of the trace metals concentration in surface water at station-4	70
Fig.17	Seasonal variation of the trace metals concentration in water at station-5	71

LIST OF FIGURES

Figure No.		Page No.
Fig.18	Seasonal variation of the trace metals concentration in surface water at station-6	71
Fig.19	Seasonal variation of the trace metals concentration in surface water at station-7	72
Fig.20	Seasonal variation of the trace metals concentration in surface water at station-8	72
Fig.21	Seasonal variation of the trace metals concentration in surface water at station-9	73
Fig.22	Seasonal variation of the trace metals concentration in surface water at station-10	73
Fig.23	Seasonal variation of the trace metals concentration in surface water at station-11	74
Fig.24	Seasonal variation of the trace metals concentration in surface water at station-12	74
Fig.25	Seasonal variation of the trace metals concentration in surface water at station-13	75
Fig.26	Concentration calibration curve for iron (Fe)	112
Fig.27	Concentration calibration curve for copper (Cu)	112
Fig.28	Concentration calibration curve for cadmium (Cd)	113
Fig.29	Concentration calibration curve for manganese (Mn)	113
Fig.30	Concentration calibration curve for lead (Pb)	114
Fig.31	Concentration calibration curve for chromium (Cr)	114
Fig.32	Concentration calibration curve for cobalt (Co)	115
Fig.33	Concentration calibration curve for nickel (Ni)	115
Fig.34	Flow sheet product of cooking liquor of the KNM	116
Fig.35	Flow sheet of the chemi-ground wood plant of the KNM	117

CHAPTER ONE

GENERAL INTRODUCTION

Bangladesh is a tropical country which is situated in the southern part of Asia and has vast areas to the south in the Bay of Bengal. Most of the country's water is drained by the Ganges, Brahmaputra and Meghna river which constitute one of the largest system in the world. Bangladesh face the most difficult task of balancing a scarce resources base. The fast growing population, mass poverty, large-scale illiteracy and regular natural calamities have made sustainable development very complicated. The country has been greatly affected by environmental degradation and depletion of its resources. The principal environmental concerns include pollution of water, decline in soil fertility, fast depletion of forest, recession of water table, increasing salinity, primary symptoms of deforestation in the northern areas, degeneration of wetland and coastal environment, destruction of inland capture fisheries etc. (Chowdury, 1994).

According to Frank and Wagnall's (1968) "Environment is the aggregation of all external and internal conditions affecting the existence growth and welfare of organisms". It basically includes a few centimeters of soil which depend on the terrestrial life, a few kilometers of air surrounding the earth without which no life can survive (Khan, 1996).

Environmental parameters exert profound effects on the behaviour, movement and survival of aquatic organism. These factors are bound to vary and the adaptive properties of the organisms fluctuate. It is always important to remember that ecological approaches must be based upon physiologically correct thinking even if the results in a probabilistic manner. The relation between aquatic organism and its environment can be complex indeed. The effects of the environment on the aquatic organism depend on the condition of the aquatic species itself, its state of nourishment, maturation of gonads etc. (Mehedi, 1994).

There are many definitions of pollution, but GESAMP (IMO/FAO/UNESCO/WMO/WHO/IAEA/UN/UNEP: Joint Group of Experts on the Scientific Aspects of Marine Pollution) formulation is widely accepted and constitutes part of the protocol of several international agreements and conventions. It states: "Pollution means the introduction by man directly or indirectly of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazard to human health, hindrance to marine activities including fishing, impairment of quality for use of sea water and reduction of amenities"(Pravdic, 1981). This definition first indicates that pollution arises from substances added to the sea by man. Although these substances cover the whole chemical spectrum, which includes nutrients, sewage, oil, metals, synthetic organic compounds, radionuclides, plastics litter, particulates etc.

In natural aquatic ecosystems, metals occur in low concentrations, normally at the nanogram to microgram per liter level. In recent times, however, the occurrence of metal contaminant especially heavy metals in excess of natural loads has become a problem of increasing concern which result environmental pollution. This situation has arisen as a result of the rapid growth of population, increased urbanization, expansion of industrial activities and exploitation of natural resources, extension of irrigation and other modern agricultural practices as well as the lack of environmental regulations (Ahmmed, 1997).

The developed and third world countries are facing global environmental problems especially related to water pollution, which have appeared in last three decades. The abnormal changes in the environment as well as water qualities are due to the negligence by human beings. The domestic sewage and industrial effluents are the major source of aquatic pollution. Human consciousness has yet not developed that need long time projects and lot of awareness to get rid of these water pollutions (Chowdury, 1994).

Bangladesh is a riverine country with approximately 3.176 millions acres of inland waters bodies are used in multidisciplinary purposes. Among the different uses of rivers fishery is one of the most important sectors but with the industrial development, this fishery also becomes threatened. Industrial waters, sewage and agricultural waste are ultimately dumped

into rivers and their quality gradually increasing with the increase in population and their demands (Bhouyain, 1993). *2 conclusion*

The WHO has also produced water quality criteria for drinking water for several chemicals including most of the heavy metals (WHO, 1984) while FAO has made a compilation of legal limits for hazardous substances to heavy metals (Nauch, 1983). Heavy metals may accumulate to toxic levels. This problems associated with heavy metal especially trace metal contamination were first highlighted in the industrially advanced countries because of their large industrial discharges and especially by incidents of mercury and cadmium pollution in Sweden and Japan (Kuriland *et. al.*, 1960; Nitta, 1972; Goldberg, 1975). Generally heavy metals are so reactive that they enter riverine or estuarine waters, many are quickly absorbed into suspended matter and will be ultimately removed to coastal sediments (Santschi *et.al.*, 1990)

For effective water pollution control and management there is a need for a clear understanding of the inputs (loads), distribution and fate of contaminants, including trace metals from land-based sources into aquatic ecosystems. In particular, the quantities and qualities need to be considered together with the distribution pathways and fate and the effects on biota (Mehedi, 1994).

Heavy metal is the term that represents a group of elements whose lower limiting density is 6 gm.cm^{-3} (Wild, 1988). However to distinguish from alkali and alkaline earth metals exceeding the atomic mass of calcium are often referred to as heavy metals (Forstner and Wittman, 1981) and most of heavy metals are nutrients too. Some heavy metals such as Zn, Cu, Mn, and Fe are essential for the growth and well being of living organisms including man. However, they are likely to show toxic effects when organisms are exposed to levels higher than normally required. Other elements such as Pb, Hg and Cd are not essential for metabolic activities and exhibit toxic properties (Ahmed, 1998).

Group of Experts on Scientific Aspects of Marine Pollution (GESAMP, 1974) has compiled joint brief reviews on a number of elements which have been considered as potential. A list of 15 elements are given such as mercury, cadmium, lead, copper, zinc, arsenic, antimony, beryllium, chromium, cobalt, manganese, nickel, silver and vanadium. Metal contamination

of the aquatic environment may lead to deleterious effect from localized inputs, which may be acutely or chronically toxic to aquatic life within the affected area. Most published data on the effects of metals on aquatic organism however report adverse effects at concentrations higher than usually found in the environment (GESAMP, 1985 & 1988).

Copper is an essential trace metal and is presumably homeostatically controlled (Bowen, 1972; Frieden, 1972; Cross *et. al.*, 1973; Bryuan, 1976; Giesy and Wiener, 1977). Although copper is essential but copper can be acutely toxic at higher concentrations (Skidmore, 1964; Black *et. al.*, 1976) and also toxic for human life (Blacow, 1972).

The cycling of iron within and through ecosystems has been extensively investigated because of the synergistic effects on the other key elemental cycles. Thus the precipitation and dissolution of iron in response to change pH and Eh are believed to be an important buffer mechanism regulating the levels of phosphorus and trace metals in aquatic environment (Mortiner, 1941, 1942 and Hutchinson, 1957). Further more several recent papers (Davies, 1970; Lewin and Chen, 1973; Murphy and Lean, 1979) have suggested that iron may on occasion be the limiting element for phytoplankton growth in some estuarine environment.

Thurberg *et. al.*, (1973) found that cadmium reduced oxygen consumption and metabolic rate in organism which might be associated with the retardation of regenerative growth.

Manganese is relatively non-toxic for organisms but toxic in higher concentration as manganese accumulated in "Manganese Psychosis" is known as brain disease. River water containing manganese more than 0.05ppm, which is toxic for both aquatic plant and animal. (Setui and Seti, 1991).

The distribution of Pb in aquatic environment is of considerable interest not only from geo-chemical stand point, but also in view of potential hazards which excessive accumulation post to biological systems. This element is deposited in bones and soft tissues. Lead poisoning in children can produce brain damage, it also cause mild anemia (>0.80ppm) brain damage, vomiting, loss of appetite, kidney disfunction and finally brain damage (>0.50-0.80ppm) (Miller, 1985).



Cobalt is comparatively rare and is the thirty-second most abundant elements in the earth's crust. This element is essential for mammals, i.e. also for human beings. A lack of vitamin B causes pernicious anemia (Miller, 1985).

Nickel is extensively used for electroplating iron and other metals. It is also used in inks, fertilizers paper mills, and petroleum refining industries and the rinse waters from these operations (De, 1994).

Cr is an important component of stainless steels and high temperature alloys. Its industrial uses include electroplating and the manufacture of chemicals, pigments and primer paint for boats (Miller, 1985).

During recent years there has been an increasing awareness of the danger of heavy metal contamination of aquatic environment. The wide use of metals in different chemical forms by the industrial, agriculture and domestic sectors has resulted in a great deal of toxic metals in the environment. Increasing awareness of ecological hazards to human life, arising from the discharge of toxic metals from urban and industrial sources have invoke considerable interest in the study of levels and fate of trace metals to levels greatly in excess of those in their environment. (Zingde *et. al.*, 1976). The occurrence of metal contaminants especially heavy metals in excess of natural load has arisen as a result of rapid growth of natural sources extension of irrigation and other modern agricultural practices as well as the lack of environmental regulations (Mehedi, 1994).

In natural aquatic ecosystem, metals occur in low concentrations normally at the nano-gram to microgram per liter level. Contamination of the aquatic environment by trace elements such as mercury, lead, cadmium, arsenic, copper, zinc, and silver are difficult to assess in as much as natural levels of these materials are not well known. Despite these limitations, metal pollution has been clearly identified in many areas of the world's oceans. In some cases, usually high inputs of toxic heavy metals to the aquatic environment have resulted in ecological changes and financial losses to commercial fisheries and in isolated cases, have been hazardous to human health (Mehedi, 1994).

Heavy metals are the most toxic and persistent pollutants in fresh water systems many researches and monitoring efforts have been conducted to determine sources, transports, and fate of these metals in the aquatic environment. However, recent studies have shown that contamination artifacts have seriously compromised the reliability of many past and current analysis. These induced errors are necessary to detect trends and to identify processes that control the transport and fate of toxic heavy metals. In addition, without accurate and reliable data, it is impossible to accurately monitor the effect of costly regulations aimed at reducing metal emissions. To avoid these problems, and to enhance the quality of trace metal data, laboratories are putting substantial effort into improving protocols for sample collection, handling and analysis (Horowitz *et. al.*, 1994).

In relation to environmental pollution, heavy metals are toxic, relatively abundant and readily available as a soluble species pose the greatest threat to biological systems (Forster and Wittman, 1981). Lower concentrations of metalloids may also kill aquatic organisms and may hinder or prevent the self-purification power of a water body. In Japan Minamata disease was caused and thousands of people died from intake of fish which had accumulated mercury at danger point. Acuteness of toxicity and devastating effects of cadmium on animals were amply proved by the "Itai-itai disease" in human beings (Kobayshi, 1971). Several studies have revealed the extreme nature of cadmium to aquatic organisms (Eisler, 1971) and bio-accumulation in the food chain (Bryan and Easel, 1978; Eisler *et. al.*, 1972; Fowler & Benayoun, 1974). All aquatic organisms are composed of some trace metals. Both deficiency and excess of essential trace metals may cause a number of diseases because they perform vital fluctuations as key components of enzymes and proteins (Mehedi, 1994).

In recent times, the occurrence of metals especially the trace metals in excess or natural loads have become a problem of increasing concern. The innumerable examples of heavy metal pollution of lakes, rivers and streams in the literature are testimony to the gravity of the situations. Metal contamination of the hydrosphere probably started with Roman mining operations to have reached its peaks in surface water in Western Europe, Japan and North America and other parts of the world during the 1970. The prolonged residence time, their persistence and bio-accumulation nature in ocean media including its plants and animals are

the most significant aspects of metal contamination and endangers with a greater potential for global distribution and effect (Mehedi, 1994).

Conclusion

The effect of effluent discharges from the industries on the river system depends on the quality and quantity of the discharged water effluents is also on the dilution capacity of the receiving water bodies. On the other hand, the pollution of the both surface and ground water is rising everywhere. The industries such as paper mills, rayon mills, urea fertilizer, tanneries, oil refineries etc. are those demands so much clears water themselves, happened to the worst polluters of rivers, usually these industries are established on the bank of the river mostly. These industries discharge a huge amount of their liquid and solid trade water chemicals and sometimes-crude sewage into the river. As a result the quality of the river water is extremely going to be deteriorated and hence the aquatic organism particularly fishes and invertebrates are gradually disappearing. Man is affected by the intake of these fishery items through food chain (Islam, 1993).

Many industrial units established on the banks of the rivers. Bhairab river at the vicinity of Khulna Newsprint Mills (KNM) and Khulna Hardboard Mills (KHM) were selected for the present study to evaluate the potential hazards with regard to toxic trace metals discharged from the various processes as effluent to the river. Being a paper industry, there every change of environmental pollution around KNM and KHM due to escape of fibers and chemicals through the effluent and fuel gases. Pulp and paper mills effluents have been concerned in water pollution abatement programs primarily because of high potential input of suspended solids and oxygen consuming to natural system.

According to Hyness and Pantelow (1978) effluents may be divided into six groups, each with different degree of polluting properties. These are:

- Inert suspension of finely divided matter.
- Poisons in solution occurring in the water from many industries.
- Inorganic reducing agents such as sulfides and sulfides being the constituents of the effluents of several types of industries.
- Oil is washed into the aquatic bodies sometimes becoming a threaten for the aquatic organisms.

- Organic residues includes the effluents from a great variety of industries, most important of all is domestic sewage. These organic residues may be due to different sources but fundamentally they are common in that they contain unstable compounds which are readily oxidized in the water.
- Hot water is produced by many industries; heated effluents only hot but full of dead of organic matter and possibly also poison.

Considerable amount of metals originated from polluting activities or physical processes enter the marine environment through rivers and affect the estuarine systems. Trace metals include elements that are of key interest in relation to biogeochemical cycling processes, due to their specific properties, their reactivity and their significance as pollutants. Trace metals undergo, during their transports, numerous changes as the result of dissolution, precipitation and adsorption phenomena. The distribution patterns of trace metals among the various parts of the estuaries have been found to be very complicated as a result of a great number of simultaneous and independent physical, chemical and biological processes involved (Salomons & Forstner, 1984; GESAMP/UNESCO, 1987; Bliniski *et. al.*, 1991).

The main principle objectives of the present research involve the following points:

- To evaluate the environmental condition with regards to trace metals in Bhairab river at the vicinity of the Khulna Newsprint & Hardboard Mills;
- To assess the extent of hazards due to the effluent discharge by Khulna Newsprint & Hardboard Mills ;
- To make an appropriate policy to suggest the different governmental and non governmental organizations for taking further initiatives in these lines ;
- To overcome the existing malnutrition problems prevailing amongst the poor people living in close proximity to the study area ;
- To create public awareness regarding the existing pollution problem as well as make valuable strategic approaches in context to the traditional resource management regime;
- To motivate the scientific community to initiate further monitoring and surveillance program with respect to different physico-chemical status of water so far in this environmentally neglected area.

CHAPTER TWO

INVESTIGATED AREA AND SAMPLING STRATEGY

2.1. Description of the Investigated Area

The Bhairab river is situated in the south-west corner of Bangladesh between latitude $21^{\circ} 27' 30''$ and $22^{\circ} 30' 00''$ N and longitude $89^{\circ} 02' 00''$ and $90^{\circ} 00' 00''$ E in Khulna administrative division and includes the part of Khulna city. A total number of 165 industries are located in the Khulna zones namely Khalispur, Shirimoni and Rupsha discharging wastes into the Bhairab-Rupsha river finally fall into the Bay of Bengal through the Passur river estuary. Some match factories, Khulna shipyard and Fish processing plants from the Rupsha industrial area discharge their effluents directly into the Rupsha river. The Khulna Newsprint and Hardboard Mills, Goalpara power station, Some jute mills and Steel mills from the Khalispur industrial belt discharge untreated wastes directly into Bhairab river. Khulna Newsprint Mills continuously discharge nearly $4500 \text{ m}^3/\text{ha}$ of wastewater, which are containing high level of suspended solids ($300\text{-}500\text{mg.l}^{-1}$) and sulphate compounds. The Bhairab river reveals that chlorides, total dissolved solids and electric conductivity are alarmingly high (DOE, 1993).

The Bhairab river is the respiratory of wastes from the Khulna Metropolitan area, involving a population of over 2 million and major industrial sources. There are no sanitation and collection facilities for municipal wastes of Khulna City. The raw and decomposed sewage and human excreta from slum area on both sides of the river in Khulna and Mongla enter the Passur river and hence to the Bay of Bengal. More than 700 metric tons household garbage is discharged in this river from Khulna and Mongla area were estimated to be approximately 2.2 tins BOD/day (ESCAP, 1987) and has increased manifolds in recent years.

Khulna Newsprint Mills (KNM) established in 1959 for making a minimum quality of 52,000 tons of Newsprint paper with a view to utilizing the untapped Gewa wood

(*Excoecaria agallocha*) from Sundarbans Forest. Recently, another agro-fibrous raw materials have been discovered for making pulp from green jute. The KNM started to purchase green jute directly from the farmers and suppliers 48000 tons of Newsprint per year. The unit uses as much as 5000 cubic meter per hour of water, 4500 cubic meter per hour in turbine cooling, 700 cubic meter per hour in paper machines, 240 cubic meter per hour for process needs and balance for boiler feed. Water is used excessively by any count and should be brought down. None of the effluent-streams gets any treatment and the entire effluents are mixed up as a single stream discharges to the river. This pollution makes the river unsightly for a considerable distance around the fall, makes the water unfit for any use and seriously affect fish and other aquatic environment (Nahar, 1996).

The raw materials of KNM are classified into two raw materials, namely fibrous raw materials and non-fibrous materials. The fibrous raw materials are again classified into two types. These are woody materials and non-woody materials. Woody materials are softwood, conifers & hard wood or board leafed species are pulped and non-woody materials are various species of bamboo, ekra, nal, khagra reeds sabai, cotton and other grasses, blast fiber of jute, hem, linen, sugarcane (bagasse), ramie etc. (Salehuddin, 1992).

The non-fibrous raw materials are used in chemical additives of KNM. These raw materials are added to the pulp, which improve specific properties of paper and other paper products. The following properties such as size, alum, filters, starch and natural gums, dyes, wet-strength resins etc. play a vital role for the purpose of paper industry (Salehuddin, 1992). The residues of these raw materials finally find their way into the sea via Bhairab river.

The Khulna Hardboard Mills (KHM) has established in 1962-63. It is situated besides the KNM. The KHM has set up on the basis of Sundri tree (*Heritiera fomes*). But the Sundri tree is decreasing day by day. As a result, other trees like Korai, Babla, Katal, Payara, Bod tree etc. are used in the production of Hardboard.

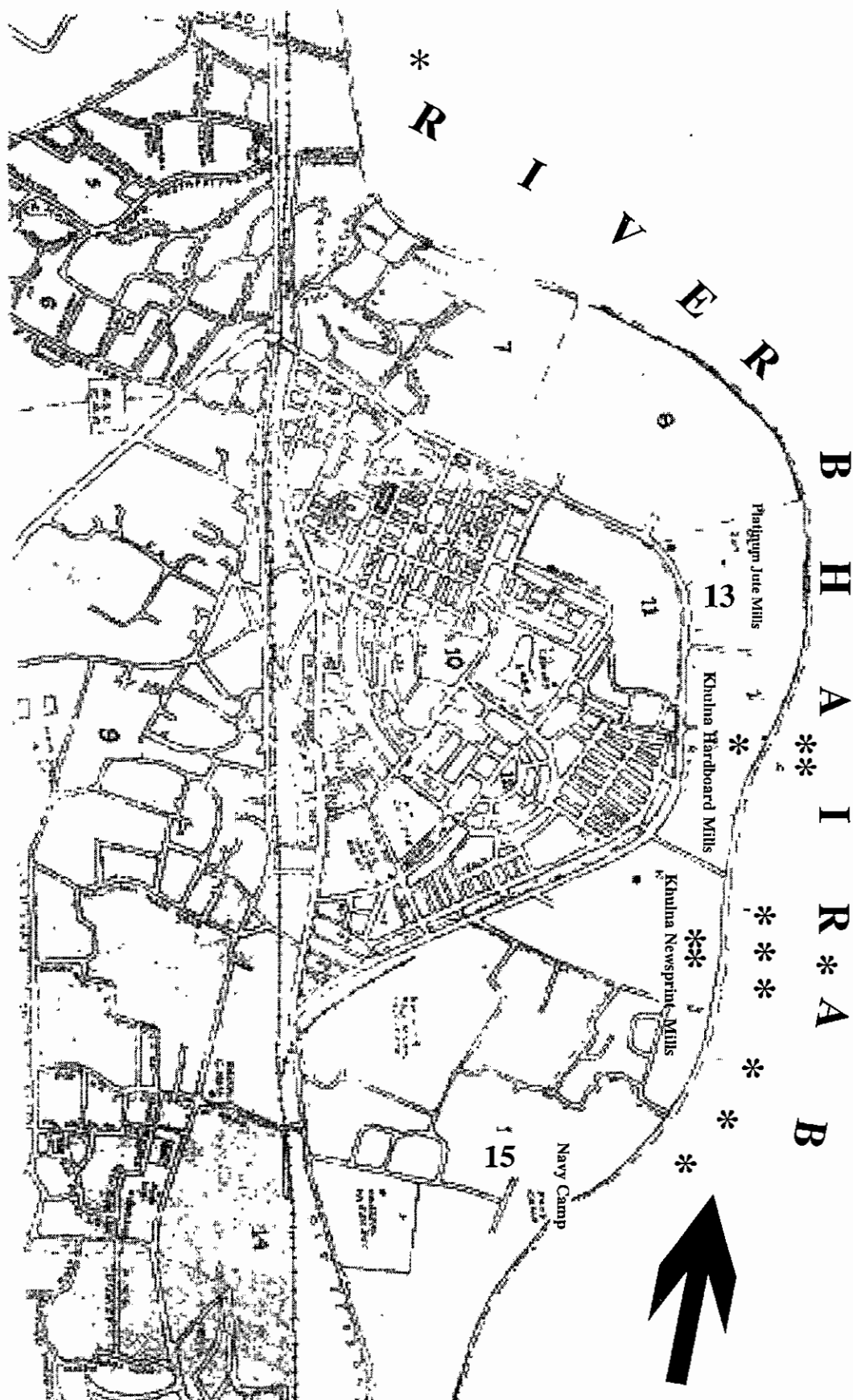
Generally wax emulsion are used. The amount of wax emulsion is 0.1kg/100-sq. meter. The yearly production of Hardboard is 160-162 square feet & monthly production is

15 lakh sq. ft. The volume of the discharge water is 700 cubic meter per day. The KHM is necessary for 30-35 ton wood per working day. The outlet drain of the discharge water is divided into three points from one drain. The KHM used river water that comes from the Khulna Newsprint Mills Ltd. In the dry season sallow water is used because the hardness of the river water is high. The production rate of the Hardboard is 150.87 lakh sq. ft. in 1998-99 (According to Director, KHM, 1999).

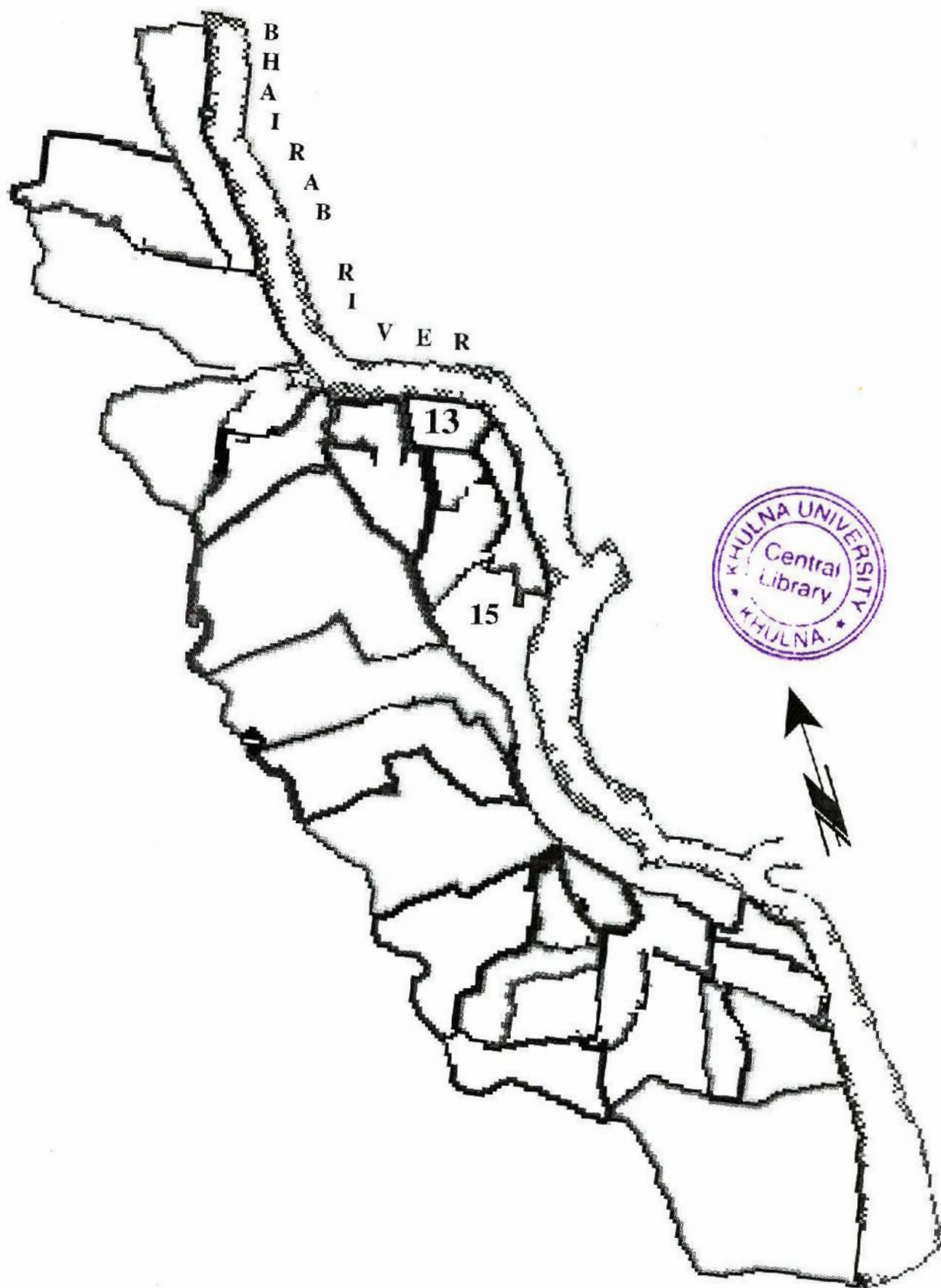
2.2. SAMPLING STRATEGY

In the present investigation surface water samples were used to analysis the level of pollution regarding some trace metals in the effluents discharged from Khulna Newsprint Mills (KNM) and Khulna Hardboard Mills (KHM) as well as the water of the Bhairab river. Total investigated area along the Hardboard mills to Navy port, namely grinding drain effluent, chemical drain effluent, discharge water from KNM, another discharge water from KNM, discharge machine water from KNM, middle of the Bhairab river, 100 meters down of the Bhairab river from KNM, 200 meters down of the Bhairab river from KNM, 300 meters down of the Bhairab river from KNM near Navy port and another station 35 miles up of the Bhairab river near Basundia, Jessore were treated as station-1, staton-2, station-3, staion-4, station-5, station-6, station-7, station-8, station-9, station-10, station-11, station-12, station-13 respectively. Samples were collected during the low tide.

The industrial effluents of the KNM were analyzed the physico-chemical status of the Bhairab river. The experiment was carried out at the area of the KNM adjacent to the Bhairab river from five sampling stations. The sampling stations were grinding sieving drain, grinding complete reject drain, mixing point with the river, side of the Bhairab river, middle of the Bhairab river were represented as station-1, station-2, station-3, station-4, station-5 respectively.



Map-1. Approximate geographical location of the investigated area, Sampling area : Khulna Newsprint & Hardboard Mills (Station 1-13 *).



Map No. 2 Map of the Khulna City and adjacent Bhairab river.
Ward No. 13 Area of the Khulna Newsprint Mills & Hardbord Mills.
Ward No. 15 Area of the Navy Camp.

CHAPTER THREE

REVIEW OF LITERATURE

Khan and Hossain (1996) studied on seasonal variation of trace metal (Cu, Pb, Zn, Cd, Mn, Fe & Cr) concentrations in water, sediment, fishes and crustacean shellfishes of the northeastern part of Bay of Bengal. They reported that the concentration of trace metals in water were low. Cadmium exhibited the highest enrichment throughout the study area with peak values in some stations of the Karnafully estuary while Pb showed higher values in some stations of the Karnafully & Meghna estuary.

Khan and Rahaman (1994) studied on the accumulation of trace metals (Fe, Cu, Zn, Cd, Hg, and Pb) in water and fishes of the Karnafully river and that concentration of trace metals were always higher in fishes in comparison with the water samples. The metal concentrations of water samples were always varies within the certified values of EQS for Bangladesh except mercury.

George (1986) studied distribution of various forms of Cd, Pb and Cu in the water samples collected from the wedge bank region (Arabian Sea). The results showed that higher concentration of all the metals in wedge Bank region compared red to those reported for coastal waters of the Gulf and western Arabian Sea.

Khan and Talukder (1995) reported that the concentration of some trace metals were high around the mouth of the Karnafully river than the Kutubdia channel Bay of Bengal (Bangladesh coast) which might be due to influence of untreated effluents discharged by various small and large industries located in the bank of the Karnafully river.

Subramanian *et. al.*, (1988) studied heavy metals (Al, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn and Pb) in the Gangcs estuary and found that the particulate were relatively enriched in all the metals, because of their fine size relative to the bed load and higher organic matter.

Mitsuali (1996) studied water quality and water pollution sources in Polyang Lake in China. The status of water quality of Polyang Lake, China in dry and wet season was described. Pollution loads generated from within the lake were insignificant, but the pollution loads contributed from the inflow river rather great, this was due to the discharges of industrial and household effluents.

Xue and Schnoor (1994) studied acid deposition and Lake Chemistry in Southwest. A water quality survey had been performed on selected lakes and streams in southwest China. The purpose of the study was to measure the concentration of acidic deposition and surface water chemistry in a region of service air pollution, forest decline and relatively sensitive geology to acid deposition.

Ahmed (1998) studied the concentrations of Fe, Cu, Zn and Cd in surface water. Five stations were selected in the Sundarban Reserved Forest (SRF) for collection of samples. The stations were Dhangmari, Chandpai, Harbarie canal, Kukilmari and Dubla Island. Concentrations of Fe, Cu, Zn and Cd water samples exceed the different certified values. So the stations of the SRF were polluted areas.

Rahman (1994) studied on the status of some trace metals observed in surface water and commercially important fishes. The concentrations of metal of surface water were not so detrimental that the presence of quality water above metals was in low concentrations on the country to different certified values. With the view of above facts, it was opined in zone of Karnafully river, near the KPRC (Karnafully paper and Rayon complex) was contaminated especially due to the effluents discharged from the KPM (Karnafully Paper Mills) and KRC (Karnafully Rayon and Chemicals), Chittagong.

Chowdury (1993) studied on the effect of effluents discharged from the Karnafully paper and Rayon complex (KPRC) on the water quality of the Karnafully river near KPRC. The concentration of some trace metals *i.e.* Cr, Mn, Fe, Cu, Zn, Cd and Pb were also analyzed from effluents water sample seasonally. The investigated area of the substantially polluted because of the polluted indicator species oligochaete was enormously raised.

Rahman (1994) studied on the water samples were collected from different stations of ship breaking area, Chittagong (Faujdarhat to Kumira) to determine the total concentrations of Fe, Cu, Pb, Cd and Hg. Finally the concentration factor of each metal were calculated to establish the relationship between concentration of metals processed in the organism and of the surrounding water body of ship breaking area of Chittagong.

Ahmmed (1997) worked on the study of trace metals in water collected from different stations of the Passur river estuary. To determine the total concentrations of Pb, Cd, Ni, Cu, Zn, Mn, Fe & Cr were analyzed seasonally. Finally, Pb exceeded the certified value.

Mehedi (1994) worked on the study of a comparative pen-picture of pollution status of the coastal belt of Bangladesh with special reference to Halisahar and ship breaking area Chittagong and found that trace metal concentrations in water, soil and the values of some physico-chemical parameters were much higher, recorded in the ship breaking area in comparison with the controlled zone (Halisahar Sea Coast) and the concentration of sometimes exceeded the different certified values.

CHAPTER FOUR

PHYSICO - CHEMICAL PARAMETERS OF WATER

4.1. INTRODUCTION

Over the past decades, the natural quality of water has been altered due to various activities of humans. Pollution has evolved gradually over time until it eventually became apparent and measurable. Recognition of a pollution problem has, therefore, usually taken considerable time and necessary control measures may take prolonged time (Chowdury, 1994).

Since the quality of water affects our lives in many ways, water should be of good quality if its aesthetic value in the scenic environment is to be appreciated. Polluted water can be the horizon for the closing of both commercial and sport fishing areas and restricting the recreational use of water bodies. Water quality can have a great influence on the ability of aquatic plants and animals to exist and grow in stream, lake, pond or bay. Use of water to manufacture many industrial products should be of good quality to prevent reduction in the quality and value of the manufactured product. Water of poor quality can affect human health since it can carry disease bearing agents, toxic chemicals etc. and it may have an unpalatable taste of a disagreeable odor. The temperature clarity and color of the water can affect the quality of the water (Palmer, 1977).

A slight increase in water temperature by the discharge of effluents from sewage treatment plant could result in the reduction of dissolved oxygen concentration. This reduction may range from acceptable to unacceptable one because of an increased oxidation rate in a given volume of the dilute effluent (Chowdury, 1994).

When pesticides, industrial wastes or municipal effluents enter a river system, a pandor's box full of problems can be frequently opened. Now-a-days, modern civilization is marked with the establishment of heavy industry that produces materials for better, comfortable and faster life. There is no doubt that it is science and technology that has brought man to this stage of prosperity. But this prosperity in return, causing severe environmental pollution by

discharging various types of industrial effluent in the water bodies adjacent to those industries. Therefore, specific knowledge is required on the effluent characteristics and potential chemical and physical changes of receiving water body to estimate the effects of effluents on the aquatic environment (Chowdury, 1994).

Pollution of surface water has become one of the most important problems about which to be concerned. It requires condition and action by individuals, civic groups, city, state and national sanitary and health departments and by industry (Palmer, 1977). Because, without water life can not survive. With a marked rise in population, a rapid growth of towns and industries and a great increase in irrigation, the demand for pure water is gradually increasing. On the other hand, the pollution of both surfaces and ground water is rising every where. Maximums of the industries are established on the bank of the river, where water is easily available for power and manufacturing processes. But, in return, these industries discharge huge amounts of the untreated liquid and solid trade wastes into the same water body. As a result, in way of the rivers, fishes and other aquatic organisms which were formally known to be abundant have now disappeared and even water supply are in danger (Chowdury, 1994).

Thus, new problems have emerged are being intensely researched and for which the appropriate global strategies have yet to be determined. Therefore, the physico-chemical parameters of surface water of the studied area were analyzed seasonally to evaluate the quality of water, tolerable for inhabiting biota.

A study was conducted to evaluate the physico-chemical status of water at the vicinity of Khulna Newsprint Mills, which were highlighted so far, in this chapter.

Introduction .



4.2. MATERIALS AND METHODS

4.2.1. Collection of Samples

Water samples were collected seasonally from five stations adjacent to the KNM of the Bhairab river in between December, 1998 and November, 1999. During low tide all the sampling were performed by using an engine boat from the selected points.

For the determination of Dissolved Oxygen and Bio-Chemical Oxygen Demand, water samples were collected in different BOD bottles, each of which was 300 ml capacity. In case of other parameters one litre capacity clean plastic bottle was used for the analysis (Uddin, 1993).

To avoid direct sun light, all the collected samples were placed into a wooden box and transported to the laboratory immediately for further analysis.

4.2.2. Preservation of Samples

The preservation procedure varies depending of the test to be performed. The samples for DO and BOD, after collection should not be allowed to remain in contact with the air or be agitated because either condition causes a change in its gaseous content. The DO sample should be "Fixed" on the spot by some prescribed reagents (such as, Manganese Sulphate $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$ and concentrated H_2SO_4 and Alkali Iodide Azide) as soon as the samples has been collected (DOE, 1983).

Immediately after the preservation, the data time and exact location should be endorsed in the level and at the same time intensive care should be taken to obtain the sample that is truly representative (DOE, 1983).

4.2.3. Method of Analysis

4.2.3.1. Water Temperature

For recording water temperature a Celsius thermometer, was dipped in the surface water for about three minutes.

4.2.3.2. Hydrogen Ion Concentration

The value of hydrogen ion concentration or *pH* was determined in the laboratory by using glass electrode digital meter (Model pw 9409, PHILIPS).

4.2.3.3. Electric Conductivity

Electric conductivity was recorded by Blackman conductivity meter of range 0-10000 μ -mhos.cm⁻¹ (model RB 3R 104, SER, 58833).

4.2.3.4. Dissolved Oxygen

Dissolved Oxygen in water samples in each sampling stations was determined at once following azide modification of Winkler method American Public Health Association, (APHA, 1976).

4.2.3.5. Bio-Chemical Oxygen Demand

The BOD bottles were filled with sample water and incubated at 20⁰ C for five days to determine the bio-chemical oxygen demand. It was measured by the azide modification method (APHA, 1976).

The value of BOD was obtained by subtracting Final Dissolved Oxygen (FDO) from Initial Dissolved Oxygen (IDO). The determination of BOD of effluents was performed after several dilutions before incubation at 20⁰C.

4.2.3.6. Chemical Oxygen Demand

Water Sample of 50 ml was placed in a reflexing flask and 1gm of Mercuric Sulphate (Hg₂SO₄) crystals and 5 ml of H₂SO₄ were added with several boiling chips. After some times 25 ml 0.25N Potassium-di-Chromate (K₂Cr₂O₇) solution was mixed again. Then the reflexing flask was attached with condenser throughout which (condenser) 70 ml H₂SO₄ was added. After well mixing of all the reagents, the flask was heated for half an hour. The sample was cooled in room temperature and titrated (the sample) against Ferus Ammonium Sulphate with ferrowing indicator. The result was expressed in mg.L⁻¹ (Hossain, 1992).

4.2.3.7. Total Suspended Solids

At first a filter paper was weighted, then a thoroughly mixed 100ml sample was filtered through the weighted filter paper. The filter paper was allowed to dry completely and re-weighted. The change in weight is multiplied by 10. Thus, total suspended solids in one liter of water samples was obtained (Andrews, 1972).

4.2.3.8. Total Dissolved Solids

A porcelain crucible was weighted and was placed on steam bath, then 100 ml of filtered sample from the TSS experiment was placed in this crucible. Evaporation took place slowly up to dryness. After cooling the crucible was placed in a dessicator and was weighted. The change in weight was multiplied by 10 to obtain the total dissolved solid (TDS) in 1 liter of water sample (Andrews, 1972).

4.2.3.9. Total Solids

To obtain the total solids the measured value of total suspended solids and total dissolved solids were added (Islam, 1993).

4.2.3.10. Total Alkalinity

Total Alkalinity was measured by APHA, 1976 method.

4.2.3.11. Chloride

The value of chloride was measured by Argentometric method (APHA, 1976).

4.3. RESULTS

4.3.1. Water Temperature [Fig.-1, Tab.-1]

Station -1

The water temperature at station-1 varied between 28⁰C and 32⁰C seasonally December 1998 to November 1999, the temperature was found to reach its maximum value 32⁰C in pre-monsoon and from the maximum value gradually reach the minimum value 28⁰C in the monsoon period.

Station -2

The water temperature at station-2 ranged between 28⁰C and 31⁰C. The temperature attained to its maximum value 31⁰C in the periods of pre-monsoon and post-monsoon and the minimum value 28⁰C was in the period of monsoon.

Station-3

The water temperature at station-3 ranged from 25⁰C to 28⁰C. The temperature attained to its maximum value 28⁰C in the period of post -monsoon and the minimum value 25⁰ C was in the monsoon period. A little seasonal variation occurred in this station.

Station -4

The water temperature at station-4 ranged between 24⁰C and 26⁰C. The temperature attained to its maximum value 26⁰C in the period of post -monsoon and the minimum value 24⁰C was in the monsoon period.

Station -5

The water temperature at station-2 ranged between 24⁰C and 25⁰C. The temperature attained to its maximum value 25⁰C in the period of post -monsoon and the minimum value 24⁰C was in the pre and post-monsoon periods.

4.3.2. Hydrogen Ion Concentration [Fig.-2, Tab.-1]

Station-1

The pH at station-1 ranged between 6.3 and 6.5. The maximum value 6.5 attained in the post monsoon period and the minimum value 6.3 was in the monsoon period.

Station-2

The pH at station-2 ranged from 6.5 to 6.9. The maximum value 6.9 attained in the post monsoon period and the minimum value 6.5 was in the monsoon period.

Station-3

The pH at station-3 ranged between 6.8 and 7.0. The maximum value attained 7.0 in the period of pre-monsoon and the minimum value 6.8 attained in the post-monsoon period.

Station-4

The pH at station-4 ranged between 7.10 and 7.25. The maximum value attained 7.25 in the period of pre-monsoon and the minimum value 7.10 was in the monsoon period.

Station-5

The pH at station-5 ranged between 7.2 and 7.4. The maximum value attained 7.4 in the period of post-monsoon and the minimum value 7.2 was in the monsoon period.

4.3.3. Electric Conductivity [Fig.-3, Tab.-1]

Station 1

The E.C at station-1 ranged from $2300\mu\text{-mhos.cm}^{-1}$ to $2400\mu\text{-mhos.cm}^{-1}$. The maximum value $2400\mu\text{-mhos.cm}^{-1}$ observed in the pre-monsoon period and the minimum value $2300\mu\text{-mhos.cm}^{-1}$ observed in the periods of monsoon and post-monsoon.

Station 2

The E.C at station-2 ranged from $2000\mu\text{-mhos.cm}^{-1}$ to $2250\mu\text{-mhos.cm}^{-1}$. The maximum value $2250\mu\text{-mhos.cm}^{-1}$ observed in the post-monsoon period and the minimum value $2000\mu\text{-mhos.cm}^{-1}$ observed in the period of monsoon.

Station 3

The E.C at station-3 ranged from $1900\mu\text{-mhos.cm}^{-1}$ to $2050\mu\text{-mhos.cm}^{-1}$. The maximum value $2050\mu\text{-mhos.cm}^{-1}$ observed in the pre-monsoon period and the minimum value $1900\mu\text{-mhos.cm}^{-1}$ observed in the period of post-monsoon.

Station 4

The E.C at station-4 ranged from $1100\mu\text{-mhos.cm}^{-1}$ to $1200\mu\text{-mhos.cm}^{-1}$. The maximum value $1200\mu\text{-mhos.cm}^{-1}$ observed in the pre-monsoon period and the minimum value $1100\mu\text{-mhos.cm}^{-1}$ observed in the period of monsoon.

Station 5

The E.C at station-5 ranged from $1100\mu\text{-mhos.cm}^{-1}$ to $1200\mu\text{-mhos.cm}^{-1}$. The maximum value $1200\mu\text{-mhos.cm}^{-1}$ observed in the pre-monsoon and post-monsoon periods and the minimum value $1100\mu\text{-mhos.cm}^{-1}$ observed in the period of monsoon.

4.3.4. Dissolved Oxygen [Fig.-4, Tab.-1]

Station 1

The dissolved oxygen at station-1 was not detected in the all periods due to low concentration.

Station 2

The dissolved oxygen at station-2 was not detected in the all periods due to low concentration

Station 3

The dissolved oxygen at station-3 ranged from 0.55mg.L^{-1} to 0.60mg.L^{-1} . The maximum concentration of dissolved oxygen observed 0.60mg.L^{-1} during the period of monsoon and the minimum concentration recorded as 0.55mg.L^{-1} during the period of pre-monsoon.

Station 4

The dissolved oxygen at station-4 ranged from 1.38mg.L^{-1} to 1.55mg.L^{-1} . The maximum concentration of dissolved oxygen observed 1.55mg.L^{-1} during the period of monsoon and the minimum concentration recorded as 1.38mg.L^{-1} during the period of post-monsoon.

Station 5

The dissolved oxygen at station-5 ranged between 1.56mg.L^{-1} and 2.11mg.L^{-1} . The maximum concentration of dissolved oxygen observed 2.11mg.L^{-1} during the period monsoon and the minimum concentration recorded as 1.56mg.L^{-1} during the period of pre-monsoon.

4.3.5. Biological Oxygen Demand [Fig.-5, Tab.-1]

Station 1

The BOD at station 1 ranged from 520 mg.L^{-1} to 530.4 mg.L^{-1} . The maximum value 530.4 mg.L^{-1} observed in the pre-monsoon period and the minimum value 520 mg.L^{-1} observed in the period of post-monsoon.

Station 2

The BOD at station-2 ranged from 204 mg.L⁻¹ to 215 mg.L⁻¹. The maximum value 215 mg.L⁻¹ observed in the period of post-monsoon and the minimum value 204 mg.L⁻¹ observed in the period of pre-monsoon.

Station 3

The BOD at station-3 ranged from 490 mg.L⁻¹ to 530.4 mg.L⁻¹. The maximum value 530.4 mg.L⁻¹ observed in the period of post-monsoon and the minimum value 490 mg.L⁻¹ observed in the period of pre-monsoon.

Station 4

The BOD at station 4 ranged from 310.4 mg.L⁻¹ to 335 mg.L⁻¹. The maximum value 335 mg.L⁻¹ observed in the period of post-monsoon and the minimum value 310.4 mg.L⁻¹ observed in the period of monsoon.

Station 5

The BOD at station-5 ranged from 220 mg.L⁻¹ to 285.6 mg.L⁻¹. The maximum value 285.6 mg.L⁻¹ observed in the period of pre-monsoon and the minimum value 220 mg.L⁻¹ observed in the period of monsoon.

4.3.6. Chemical Oxygen Demand [Fig.-6, Tab.-1]

Station 1

The COD at station-1 ranged between 3400 mg.L⁻¹ and 3829 mg.L⁻¹. The maximum value 3829 mg.L⁻¹ observed in the period of pre-monsoon and the minimum value 3400 mg.L⁻¹ observed in the period of monsoon.

Station 2

The COD at station-2 ranged between 1800 mg.L⁻¹ and 2100 mg.L⁻¹. The maximum value 2100 mg.L⁻¹ observed in the period of pre-monsoon and the minimum value 1800 mg.L⁻¹ observed in the period of post-monsoon.

Station 3

The COD at station-3 ranged from 700 mg.L⁻¹ to 800 mg.L⁻¹. The maximum value 800 mg.L⁻¹ observed in the period of pre-monsoon and the minimum value 700 mg.L⁻¹ observed in the period of post-monsoon.

Station 4

The COD at station-4 ranged from 10 mg.L⁻¹ to 15.5 mg.L⁻¹. The maximum value 15.5 mg.L⁻¹ observed in the period of post-monsoon and the minimum value 10 mg.L⁻¹ observed in the period of monsoon.

Station 5

The COD at station-5 ranged between 5 mg.L⁻¹ and 6.02 mg.L⁻¹. The maximum value 6.02 mg.L⁻¹ observed in the period of pre-monsoon and the minimum value 5 mg.L⁻¹ observed in the period of monsoon.

4.3.7. Total Suspended Solids [Fig.-7, Tab.-1]

Station 1

The Total Suspended Solids at station-1 ranged from 350 mg.L⁻¹ to 400 mg.L⁻¹. The maximum value 400 mg.L⁻¹ observed during the period of pre-monsoon and post-monsoon. The minimum value 350 mg.L⁻¹ of TSS showed in the monsoon period.

Station 2

The Total Suspended Solids at station-2 was ranged from 200 mg.L⁻¹ to 250 mg.L⁻¹. The maximum value 250 mg.L⁻¹ observed during the period of post-monsoon. The minimum values 200 mg.L⁻¹ of TSS showed in the monsoon and post-monsoon periods.

Station 3

The Total Suspended Solids at station -3 was ranged between 200 mg.L⁻¹ and 250 mg.L⁻¹. The maximum value 250 mg.L⁻¹ observed during the period of pre-monsoon and the minimum value 200 mg.L⁻¹ of TSS showed in the monsoon period.

Station 4

The Total Suspended Solids at station-4 was ranged from 200 mg.L⁻¹ to 250 mg.L⁻¹. The maximum value 250 mg.L⁻¹ observed during the period of monsoon. The minimum value 200 mg.L⁻¹ of TSS showed in the pre and post-monsoon period.

Station 5

The Total Suspended Solids at station-5 was 200 mg.L⁻¹. The same values were observed in the all periods.

4.3.8. Total Dissolved Solids [Fig.-8, Tab.-1]

Station 1

The Total Dissolved Solids varied between 2300 mg.L⁻¹ and 2400 mg.L⁻¹. The value of TDS was observed 2400 mg.L⁻¹ during the pre and post monsoon periods and the minimum value 2300 mg.L⁻¹ was found in the period of monsoon.

Station 2

The Total Dissolved Solids at station-2 varied between 2900 mg.L⁻¹ and 3100 mg.L⁻¹. The maximum value of TDS was observed 3100 mg.L⁻¹ during the pre-monsoon period and the minimum value 2900 mg.L⁻¹ was found in the period of post-monsoon.

Station 3

The Total Dissolved Solids at station-3 varied between 400 mg.L⁻¹ and 500 mg.L⁻¹. The maximum value of TDS was observed 500 mg.L⁻¹ during the pre & post-monsoon periods and the minimum value 400 mg.L⁻¹ was found in the period of monsoon.

Station 4

The Total Dissolved Solids at station-4 varied between 200 mg.L⁻¹ and 300 mg.L⁻¹. The maximum value of TDS was observed 300 mg.L⁻¹ during the period of post-monsoon and the minimum 200 mg.L⁻¹ was found in the period of monsoon and pre-monsoon.

Station 5

The Total Dissolved Solids at station-5 varied between 350 mg.L⁻¹ to 400 mg.L⁻¹. The maximum values of TDS was observed to 400 mg.L⁻¹ pre & post-monsoon and the minimum value 350 mg.L⁻¹ was found in the period of monsoon.

4.3.9. Total Solids [Fig.-9, Tab.-1]

Station 1

The Total Solids at station-1 ranged between 2700 mg.L⁻¹ and 2800 mg.L⁻¹. The maximum solids 2800 mg.L⁻¹ observed in the pre-monsoon period. The minimum value 2700 mg.L⁻¹ was observed during the monsoon and post-monsoon periods.

Station 2

The Total Solids at station-2 ranged between 3000 mg.L⁻¹ and 3300 mg.L⁻¹. The maximum solids 3300 mg.L⁻¹ observed in the pre-monsoon period and the minimum value 3000 mg.L⁻¹ observed in the post-monsoon period.

Station 3

The Total Solids at station-3 ranged between 550 mg.L⁻¹ and 700 mg.L⁻¹. The maximum solids 700 mg.L⁻¹ observed in the pre-monsoon period and the minimum 550 mg.L⁻¹ observed in the post-monsoon period.

Station 4

The Total Solids at station 4 ranged between 350 mg.L⁻¹ and 400 mg.L⁻¹. The maximum solids 400 mg.L⁻¹ observed in the pre-monsoon and post-monsoon periods. The minimum 350 mg.L⁻¹ observed in the monsoon period.

Station 5

The Total Solids at station-5 ranged from 500 mg.L⁻¹ to 650 mg.L⁻¹. The maximum solids 650 mg.L⁻¹ was observed in the post-monsoon period and the minimum value 500 mg.L⁻¹ observed in the monsoon period.

4.3.10. Total Alkalinity [Fig.-10, Tab.-1]

Station 1

The Total Alkalinity at station-1 ranged from 80 mg.L⁻¹ to 88 mg.L⁻¹. The maximum concentration observed 88 mg.L⁻¹ in the period of post-monsoon and the minimum value 80 mg.L⁻¹ observed in the period of monsoon.

Station 2

The Total Alkalinity at station-2 ranged between 75 mg.L⁻¹ and 80 mg.L⁻¹. The maximum concentration observed 80 mg.L⁻¹ in the period of pre-monsoon and the minimum value 75 mg.L⁻¹ was observed in the period of monsoon.

Station 3

The Total Alkalinity at station-3 ranged between 53 mg.L⁻¹ and 57 mg.L⁻¹. The maximum concentration was 57 mg.L⁻¹ in the period of pre-monsoon and the minimum value 53 mg.L⁻¹ observed in the period of post-monsoon.

Station 4

The Total Alkalinity at station-4 ranged between 38 mg.L⁻¹ and 40 mg.L⁻¹. The maximum concentration 40 mg.L⁻¹ observed in the period of pre-monsoon and the minimum value 38 mg.L⁻¹ observed in the period of monsoon.

Station 5

The Total Alkalinity at station-5 ranged from 32 mg.L⁻¹ to 34 mg.L⁻¹. The maximum concentration 34 mg.L⁻¹ observed in the period of pre-monsoon and the minimum value 32 mg.L⁻¹ observed in the period of monsoon.

4.3.11. Chloride [Fig.-11, Tab.-1]

Station-1

The chloride at station-1 ranged from 100 mg.L⁻¹ to 125 mg.L⁻¹. The highest value 125 mg.L⁻¹ observed in pre-monsoon and the minimum value 100 mg.L⁻¹ observed in the post-monsoon period.

Station-2

The chloride at station-2 ranged from 100 mg.L⁻¹ to 110 mg.L⁻¹. The highest value 110 mg.L⁻¹ observed in pre-monsoon and post-monsoon periods and the minimum value 100 mg.L⁻¹ observed in the post-monsoon period.

Station-3

The chloride at station-3 ranged from 95 mg.L⁻¹ to 100 mg.L⁻¹. The highest value 100 mg.L⁻¹ observed in pre and post-monsoon periods and the minimum value 95 mg.L⁻¹ observed in the post-monsoon period.

Station-4

The chloride at station-4 ranged from 100 mg.L⁻¹ to 105 mg.L⁻¹. The highest value 105 mg.L⁻¹ observed in the post-monsoon period and the minimum value 100 mg.L⁻¹ in the pre-monsoon and monsoon periods.

Station-5

The chloride at station-5 ranged from 80 mg.L⁻¹ to 85 mg.L⁻¹. The highest value 85 mg.L⁻¹ observed in the pre-monsoon period and the minimum value 80 mg.L⁻¹ observed in the monsoon and post-monsoon periods.

Table No.1 Seasonal Variation of Some Physicochemical Parameters in Different Stations.

No. of station	Location	Season	Temp. (°C)	pH	E.C (micro-Mhos.cm ⁻¹)	DO (mg.L ⁻¹)	BOD (mg.L ⁻¹)	COD (mg.L ⁻¹)	TSS (mg.L ⁻¹)	TDS (mg.L ⁻¹)	TS (mg.L ⁻¹)	T.Alka (mg.L ⁻¹)	Chloride (mg.L ⁻¹)
Station 1	Grinding sieving drain	Pre-monsoon	32	6.4	2400	0	530.4	3829	400	2400	2800	85	125
		Monsoon	28	6.3	2300	0	525	3400	350	2300	2650	80	120
		Post-monsoon	30	6.5	2300	0	520	3500	400	2400	2800	88	100
Station 2	Grinding complete Reject drain	Pre-monsoon	31	6.8	2200	0	204	2100	200	3100	3300	80	110
		Monsoon	28	6.5	2000	0	210	2000	200	3000	3200	75	100
		Post-monsoon	31	6.9	2250	0	215	1800	250	2900	3150	77	110
Station 3	Mixing point with The river	Pre-monsoon	27	7.0	2050	0.55	530.4	800	250	500	750	57	100
		Monsoon	25	6.9	2000	0.60	490	750	200	400	600	56	95
		Post-monsoon	28	6.8	1900	0.57	510.4	700	230	500	730	53	100
Station4	Side of the Bhairab river	Pre-monsoon	26	7.25	1200	1.42	326.4	12.5	200	200	400	40	100
		Monsoon	24	7.10	1100	1.55	310.4	10	250	200	450	38	100
		Post-monsoon	26	7.15	1150	1.38	335	15.5	200	300	500	39	105
Station 5	Middle of the river	Pre-monsoon	24	7.3	1200	1.56	285.6	6.02	200	400	600	34	85
		Monsoon	24	7.2	1100	2.11	220	5.00	200	350	550	32	80
		Post-monsoon	25	7.4	1200	1.70	250	5.50	200	400	600	33	80

EC= Electric Conductivity, DO= Dissolved Oxygen , BOD=Bio-chemical Oxygen Demand , COD=Chemical Oxygen Demand , TSS=Total Suspended Solids , TDS=Total Dissolved Solids , TS=Total Solids , T.Alka=Total Alkalinity.



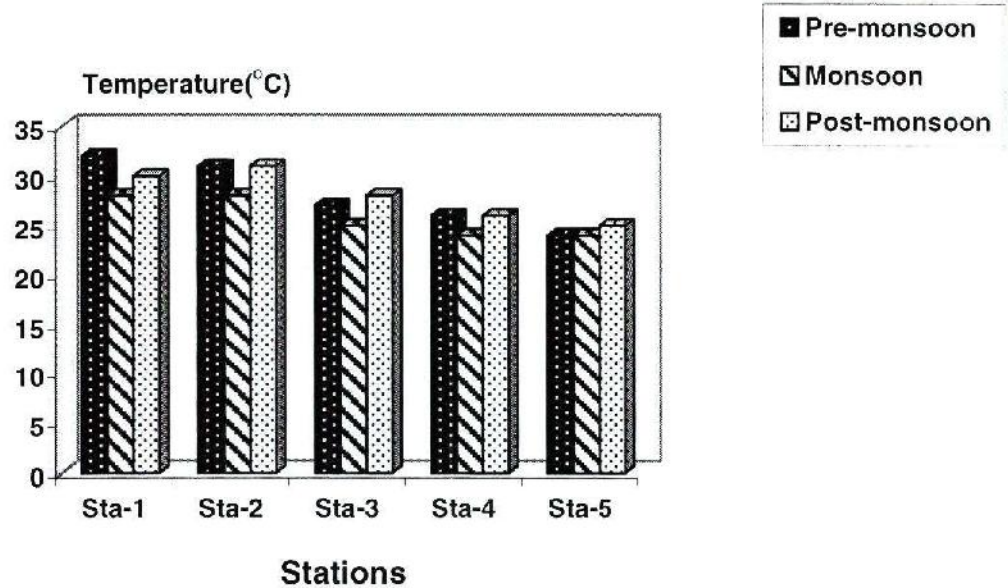


Fig.-1 Sesonal Variation in Surface Water Temperature ($^{\circ}\text{C}$) in Different Stations

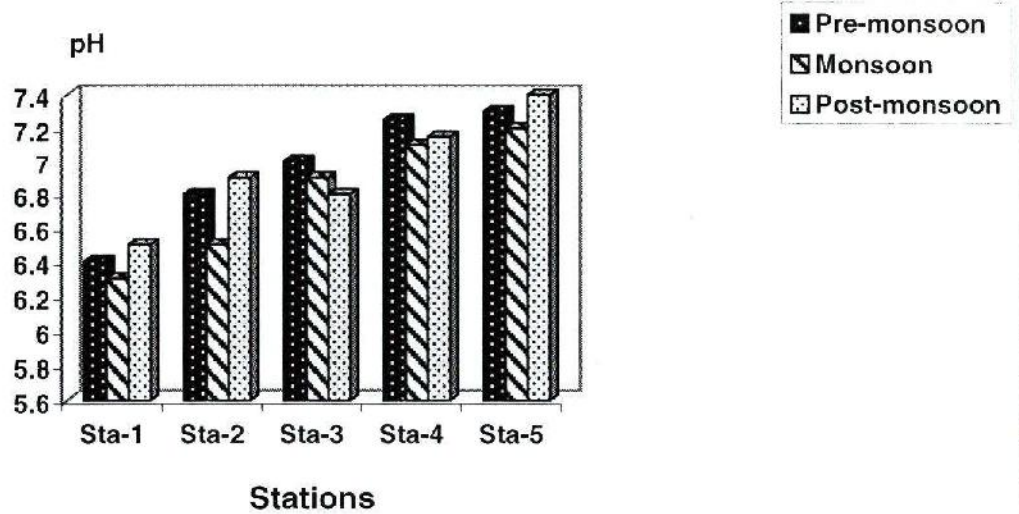


Fig.-2 Sesonal Variation in Surface Water pH in Different Stations.

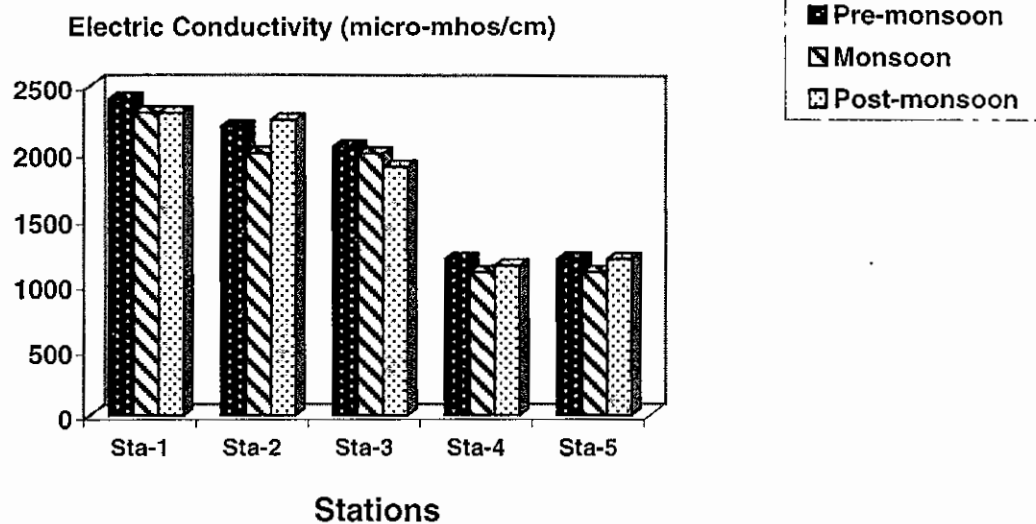


Fig.-3 Seasonal Variation in Surface Water Electric Conductivity in Different Stations.

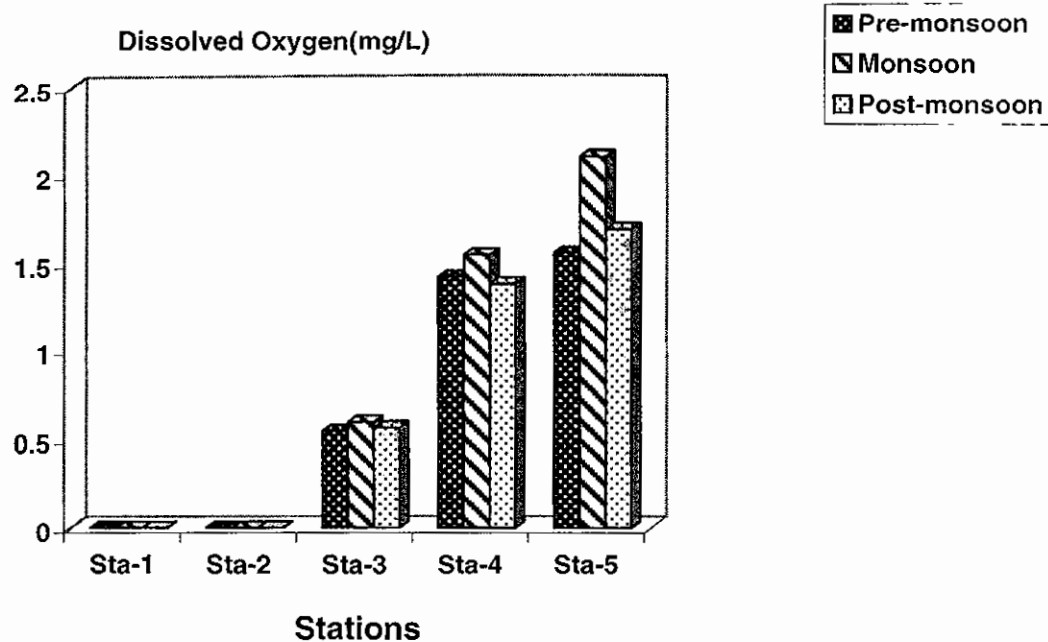


Fig.-4 Seasonal Variation in Surface Water Dissolved Oxygen in Different Stations .

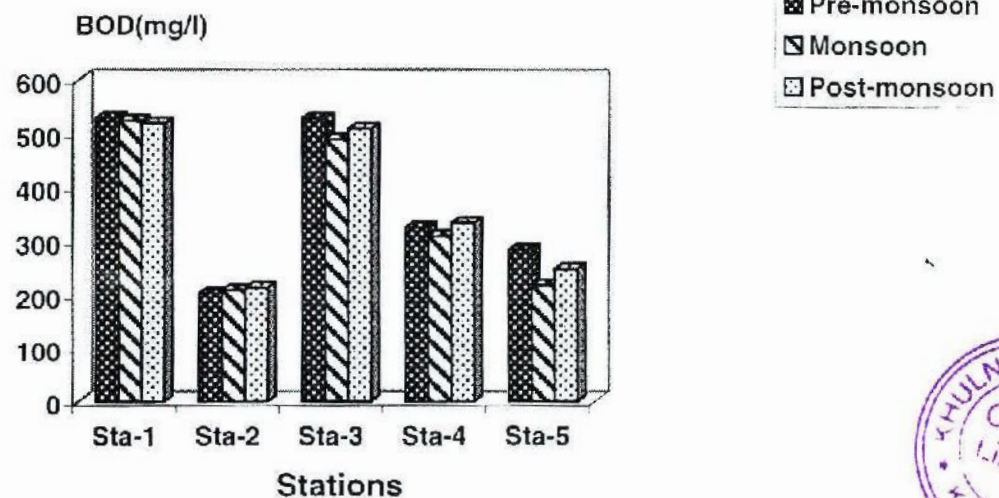


Fig.-5 Sesonal Variation in Surface Water BOD(mg/l) in Different Stations.

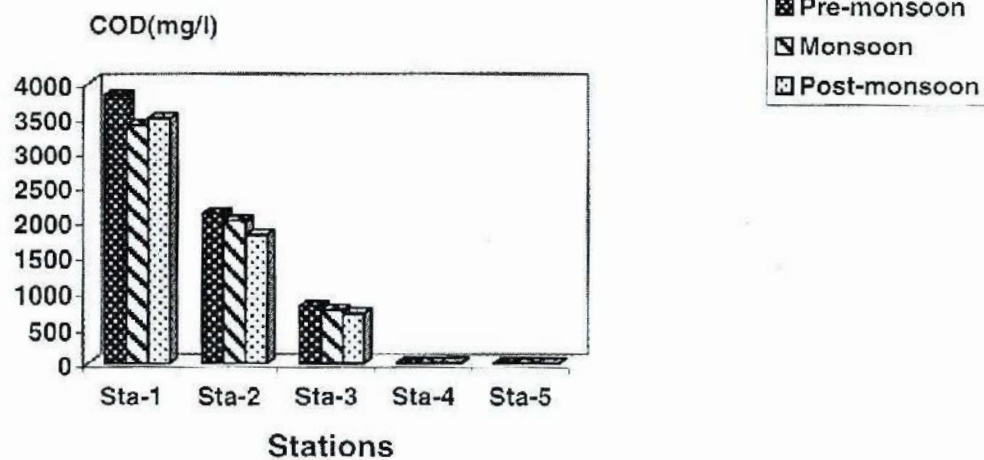


Fig.-6 Sesonal Variation in Surface Water COD(mg/l) in Different Stations.

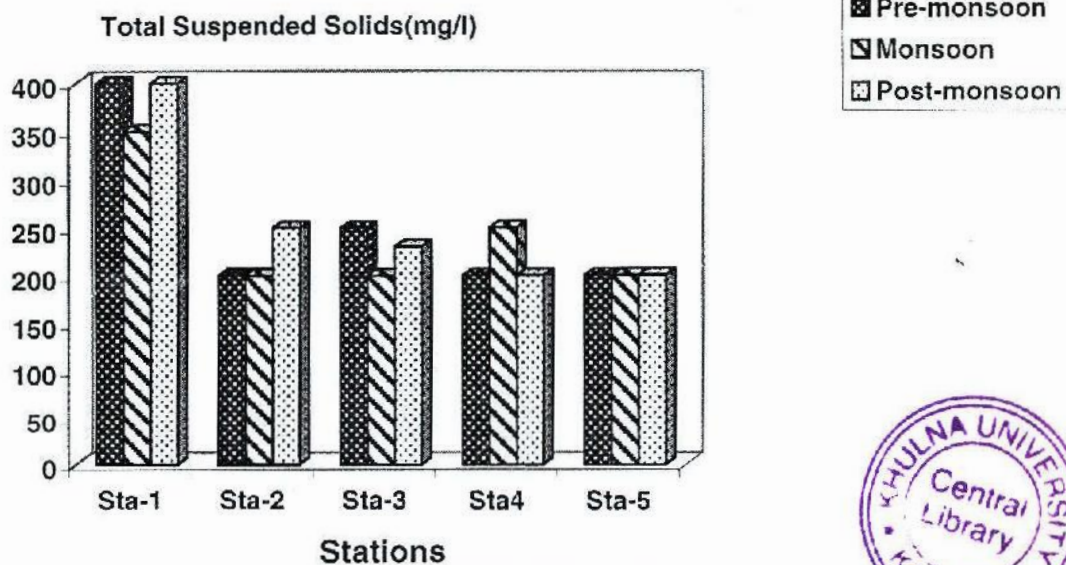


Fig.-7 Sesonal Variation in Surface Water Total Suspended Solids(mg/l) in Different stations

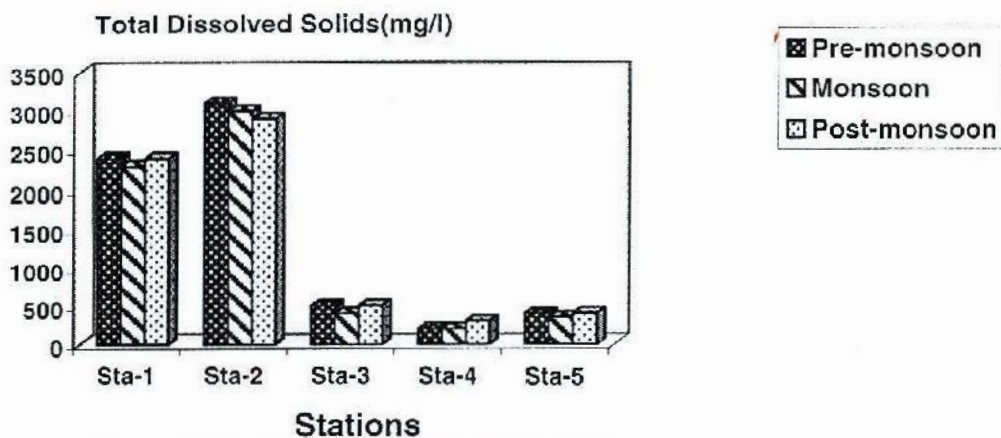


Fig.-8 Sesonal Variation in Surface Water Total Dissolved Solids(mg/l) in Different Stations.

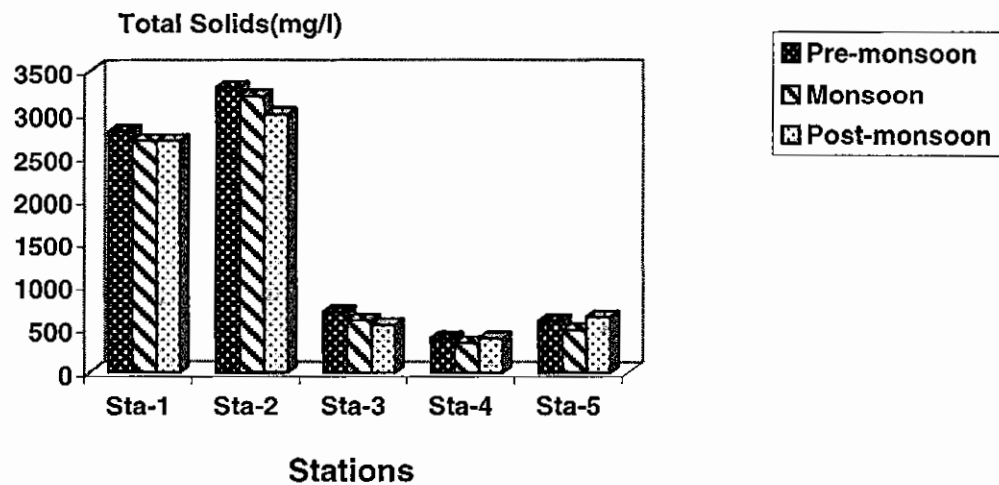


Fig.-9 Seasonal Variation in Surface Water
Total Solids(mg/l) in Different Stations.

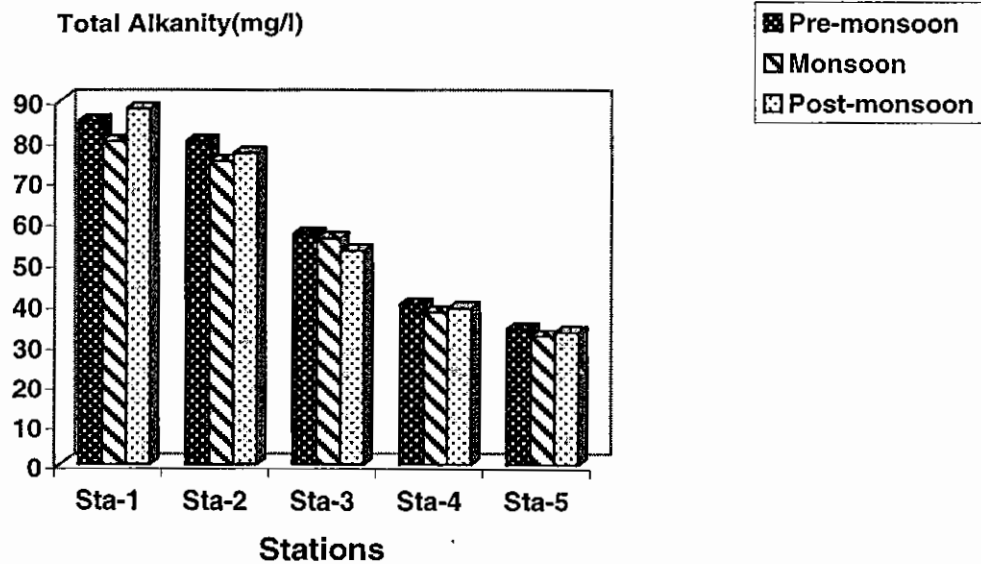


Fig.-10 Seasonal Variation in Surface Water
Total Alkanity(mg/l) in Different Stations

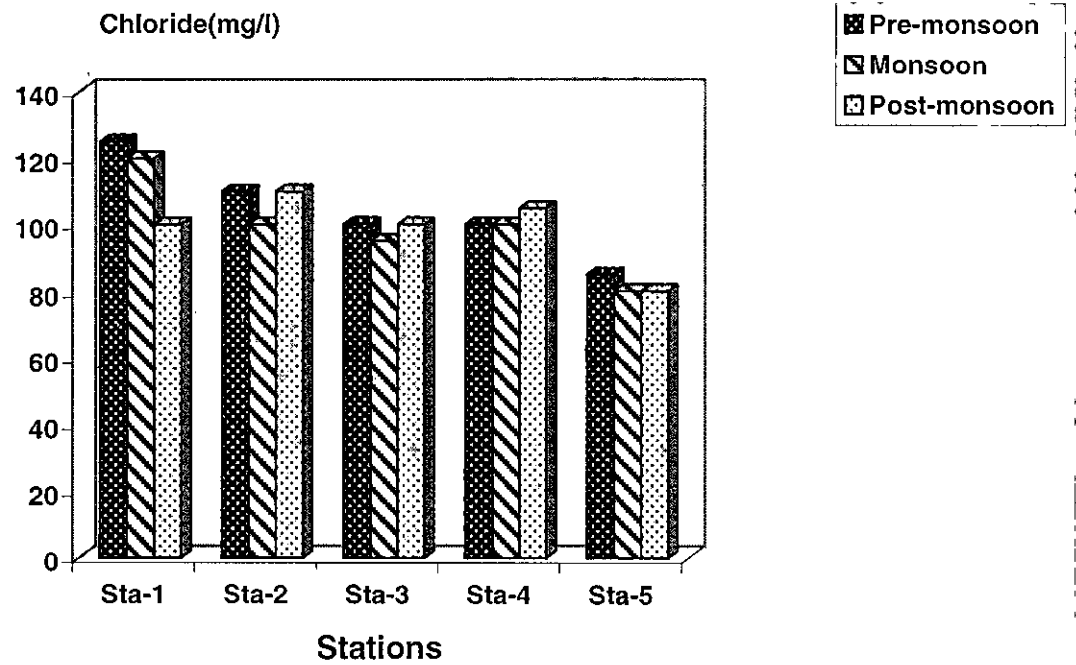


Fig.-11 Seasonal Variation Chloride(mg/l) in Different Stations.

4.4. DISCUSSION

4.4.1. Water Temperature [Fig.-1, Tab.-1]

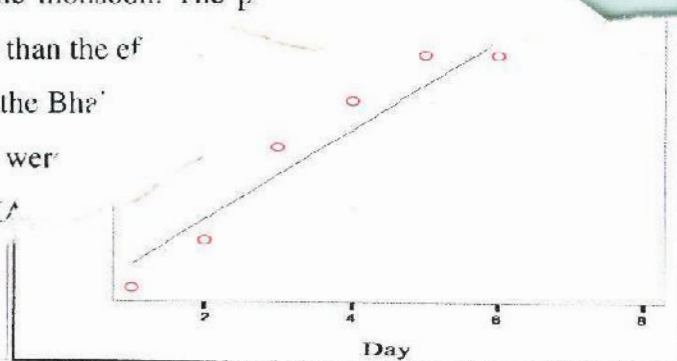
During the period of investigation the maximum temperature of the effluent at station-1 (grinding sieving drain) was recorded as 32⁰C in the period of pre-monsoon and the minimum temperature as 24⁰ C at station-5 (middle of the Bhairab river) in the periods of monsoon & pre-monsoon.

The standard values for the industrial effluents of Environmental Quality Standards (EQS) for Bangladesh (1991) were 40⁰C and 45⁰C in the winter and summer months respectively. The highest 32⁰C values of temperature at station-1 did not exceed the EQS values.

The fluctuations of water temperatures at stations-3, 4, 5 were treated as mixing point of the river, side of the river and middle of the Bhairab river respectively, were more or less same at all seasonal except station-1 and 2. It seemed that changes in the water temperature were mainly induced by variations in the atmospheric temperature. Chandran *et al.*, (1984), Qusim & Gopinathan (1969) and Dehadrai (1970) had also reported similar finding in Vellar estuary Cochin backwaters and Mormugao Bay respectively. Remain *et. al.*, (1983) also observed seasonal fluctuation in temperature in Cochin backwaters. The findings of Islam (1993) substantiate the present work. Bhouyain (1979) worked on the effect of industrial pollution of the biology of the Karnafully river and reported that the respective industries (KPM and KRC) were responsible for the change of water temperature of the river. The present work correlates with the result of Bhouyain (1979). Islam (1993) worked on the influence of the effluents discharged by the KPM and KRC on the physicochemical parameters of the Karnafully river and also found the same result of the present investigation.

Islam (1993), Hossain (1992), UNEP and WHO (1990), Klein (1962) and Moore *et al.*, (1960) stated that many industries were the cause of increasing the temperature of receiving water body in which their effluents were discharged. The present work similitude's with the above authors.

The maximum values of pH observed as 7.4 at station minimum was 6.3 at station-1 during the monsoon. The pH of grinding reject drain effluent were lower than the effluent of the river, side of the river and the middle of the Bhakra River. It was observed that the effluents of the KPRC were within the permissible limits. Moore *et. al.*, (1960), APHA (1970), Campbell (1978), Paul (1981) and Iyer (1982) coincide with the present study.



Devi *et. al.*, (1983) and Qasim (1969) b
backwaters. They found that the pH of *ssambicus* stored in ice: (a) Bar chart (b)
coincide with the three stations (3, 4 & 5) ssion line

The standard value of pH for industrial effluents for Bangladesh (1991) ranged between 6.5 and 8.5 (Table 1).

Water Standard (USPH) was 6.0-8.5 terized by a grayish color, aqueous and transparent stations varied (6.3-7.4) in the present and characteristic smell. Scales adhered firmly to of EQS for Bangladesh.

idity flattened extremely until sunken. The gills lost

The maximum value of Electric Conductivity was recorded at station-1 during the pre-monsoon and station-5 during monsoon period. The values of Electric Conductivity at station-1, 2, 3 were higher than those of the other stations. This is in agreement with Bhouyain (1983) and Islam (1993) studies. The water in the lake, river, stream etc. is fresh water. The above statements well agree with the present investigation.

The maximum (2400 micro-mhos.cm⁻¹) and the minimum (1100 micro-mhos.cm⁻¹) values of EC were recorded at station-1 during the period of pre-monsoon and station 4 and 5 during

the same period of monsoon, whereas the standard value for industrial effluents of EQS for Bangladesh (1991) was 1200 micro-mhos.cm⁻¹. The EC of the effluent of the KNM exceeded several times occasionally than the EQS value.

4.4.4. Dissolved Oxygen [Fig.-4, Tab.-1]

The maximum values of Dissolved Oxygen (DO) was recorded as 2.11 mg.L⁻¹ at station-5 during the period of monsoon and the minimum value 0 mg.L⁻¹ at station-1 and 2 during the all periods. In the present investigation the values of DO were always lower at station 1 and 2 and gradually increased 3, 4 and 5. These might be due to the influence of effluents discharged from the KNM. Fox (1977) stated that the effluents of pulp and paper mills had been implicated in oxygen depletion, toxicity and production of taste and odor in the receiving water and its aquatic communities. The present investigation correlates with the above author.

The values of DO varied seasonally and were higher during the period of monsoon at station-3, 4 and 5. Similar observations also noticed by Islam (1993) in the Karnafully river and Dehadrai (1970) in the Mandovi and Zuari estuaries and Rajendran (1974) in Vellar estuary and stated that in general the DO values were higher during the monsoon and pre-monsoon seasons. The present work coincides with the above authors.

The DO values recorded at station-1 and 2 might be due to the high content of suspended and dissolved solids with the effluent discharged from the KNM. Unithan *et. al.*, (1975) and Nair *et. al.*, (1984) stated that DO was considerably influenced by sewage discharged and Hossain (1992) and Islam (1993) stated that the TSS and TDS were responsible for water DO values. Similar results were found in the present investigation and coincide with the above author.

Nair *et. al.*, (1983) stated that the pulp mills effluents might be cited as the reason for the significant level of oxygen depletion of Kallada river. Islam (1993) also stated that the depletion of DO in the effluent and the effluent discharged area was due to the effluents discharged from the KNM. The present work similitude's with the works of Nair *et. al.*, (1983) and Islam (1993).

The standard value of DO for industrial effluent of EQS 4.5 to 8 mg.L⁻¹ but in the present study, the DO values were always lower than the EQS value.

4.4.5. Bio-Chemical Oxygen Demand [Fig.-5, Tab.-1]

The maximum Bio-Chemical Oxygen Demand (BOD) values at station-1 and 3 during the same period of pre-monsoon and the station-2 during the period of pre-monsoon. The BOD of the station-3 (effluent) was higher than the other stations (2, 4 and 5) during the period of investigation. Islam (1993) and Bhuiyain (1979) made similar observations during their study on the effluent of the Karnafully paper and Rayon complex (KPRC). Mahmood *et al.*, (1988), Hossain *et al.*, (1988), Unnithan *et al.*, (1975), Vijayan *et al.*, (1975) and Remani (1979) also found the same result and stated that the higher values of BOD might be due to the wastes discharged from municipal and urban sewerage, which is well agreement with the present investigation.

Islam (1993) and Uddin (1993) during their investigations found that the BOD values were always higher in the discharged area. In the present study the similar values were observed. The values of BOD were inversely proportional to the values of DO during the present investigation *i.e.* when the BOD values increased the consumption of oxygen by the microbes for their oxidation process. Hossain *et al.*, (1983) and Hossain (1992) stated the higher values of BOD in the disposal zone were due to the consumption of oxygen for the oxidation of large amount of wastes, discharged from the municipal sewerage and surface run off due to the rainfall. Islam (1993) also observed the same results during his study on the physico-chemical parameters of the Karnafully river. The observations of the authors well agree with the present findings.

The standard value of BOD for industrial effluents of Environmental Quality standards (EQS) for Bangladesh (1991) was 75mg.L⁻¹ whereas the minimum recorded value 204mg.L⁻¹ at station-2 during the period of pre-monsoon exceeded the EQS value. Islam (1993) also found the same result which similitude's with the present findings.

4.4.6. Chemical Oxygen Demand [Fig.- 6, Tab.-1]

The maximum Chemical Oxygen Demand (COD) value recorded as 3829 mg.L^{-1} at station-1 during the period of pre-monsoon and the minimum 5.00 mg.L^{-1} at station-5 during the period of monsoon. During the period of investigation the values of COD at (station-1 and 2) were always higher in comparison with the other stations (3, 4 and 5). These higher values might be due to the high concentration of organic and inorganic substances with the effluent discharged from the KNM. Islam (1993) and Hossain (1992) observed higher values of COD in the industrial effluents due to same reason.

The values of COD at station-1, 2 and 3 (effluent) were always slightly higher than the station- 4 and 5. Uddin (1993) and Islam (1993) also found higher values of COD in the effluent discharged areas than the other areas, which well agree with the present findings.

Ganapathi and Raman (1973) found higher values of COD in the Visakhapatnam harbour waters than in the base-line open seawater. Islam (1993) and Uddin (1993) found similar trend in COD values which also similitude with the present investigation, high amount of COD values were also recorded. The findings of above authors coincide with the present work.. The standard value of COD for industrial effluents of EQS for Bangladesh (1991) was determined as 200 mg.l^{-1} , whereas at station-1, grinding sieving drain was $3,829 \text{ mg.L}^{-1}$ recorded during the period of pre-monsoon, the highest value in the effluents of KNM at station 1, 2 and 3 were always higher than the EQS standard value.

4.4.7. Total Suspended Solids [Fig.-7, Tab.-1]

The maximum value of Total Suspended Solids (TSS) was as 400 mg.L^{-1} at station-1 during the period of pre-monsoon and post-monsoon and the minimum value was 200 mg.L^{-1} recorded at the station-5 during all the periods and station-2 during the periods of pre-monsoon and monsoon and station-4 during the periods of pre and post-monsoon . The value of TSS at station-1 was comparatively always higher than the other stations (2, 3, 4 and 5) during the period of investigation. Similar patterns were observed by Islam (1993) when he worked on the influence of the effluents from the KPRC, which coincides with the presents work. The higher values of TSS at station-1 might be due to the effluents, which contained

several types of organic and inorganic materials within it. The low values of TSS in the effluent discharged area were might be due to the dilution of the effluents with river water. Islam (1993) also found similar trends and the present investigation correlate with the findings of Islam.

The standard value for industrial effluents of EQS for Bangladesh (1991) was 150 mg.L^{-1} . But in the present investigation, the effluents of KNM did not maintain the standard limit. The highest value 400 mg.L^{-1} to TSS at station-1 was higher than the EQS standard for Bangladesh.

4.4.8. Total Dissolved Solids [Fig.-8, Tab.-1]

The maximum value was as 3100 mg.L^{-1} at station-2 during the periods of pre-monsoon and the minimum value 200 mg.L^{-1} at station-4 during the pre-monsoon and monsoon periods. The values of Total Dissolved Solids (TDS) at station-1 and 2 were much higher than the other three stations (3, 4 and 5) in the present investigation. Islam (1993) observed higher values of TDS in the effluents than the effluent discharged area, side of the river at the vicinity of KNM and the middle of the Bhairab river. The present findings correlate with the findings of Islam. The standard value of TDS of Environmental Quality Standard (EQS) for Bangladesh (1991) was 2100 mg.L^{-1} . In the present investigation the highest value (3100 mg.L^{-1}) of TDS at station-2 during the period of pre-monsoon was much higher than the EQS value which might be due to the presence of huge amount of organic and inorganic substances discharged from the KNM.

Islam (1993) in his study on the influence of effluent discharged by the KPM and KRC on the physico-chemical parameters found lower values of TDS than the EQS value. Thus, the present investigation did not agree with the findings of Islam (1993).

4.4.9. Total Solids [Fig.-9, Tab.-1]

The maximum value of Total Solids (TS) was as 3300 mg.L^{-1} at station-2 during the period of pre-monsoon and the minimum value was 350 mg.L^{-1} at station-4 during the period of monsoon. In the present investigation the values of TS at stations-1 and 2 (effluent) were always higher in comparison with other stations (3, 4 and 5). Islam (1993) also found higher

values in the effluents of KPRC than the effluents discharged area and the controlled area. The present investigation is well agreement with the findings of Islam (1993).

The standard value of TS was 2250 mg.L^{-1} for the industrial effluents of EQS (1991) for Bangladesh. In the present investigation, the highest value of TS at station-2 (grinding complete reject drain) was recorded as 3300 mg.L^{-1} in the period of pre-monsoon. These values did not follow the EQS value and might be harmful for the water as well as the biota of the Bhairab river.

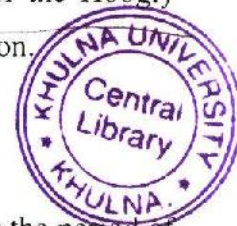
4.4.10. Total Alkalinity [Fig.-10, Tab.-1]

The maximum value of total alkalinity was as 88 mg.L^{-1} at station-1 during the post-monsoon period and the minimum value was 32 mg.L^{-1} at station-5 during the period of monsoon. The total alkalinity of the effluents at station 1 and 2 were always higher than the effluent of the discharged area mixing point of the river, side of river and the middle of the Bhairab river in the present investigation. Even the total alkalinity of effluent discharged area was slightly higher than the middle of the river in the present investigation. Hossain (1992) and Islam (1993) also found similar trends during their investigation period. The present findings are well agreement with above authors.

In the present investigation, the values of total alkalinity were higher in the effluent discharged area than the middle of Bhairab river. These higher values might be due to the effluent discharged from the KNM. Mahmood *et. al.*, (1988) stated that higher alkalinity was found in the municipal waste disposal area of the Karnafully river. Seth and Bhaskarn (1950) found higher values of total alkalinity in the industrial waste disposal area of the Hoogly river. The observations of the above authors substantiate the present investigation.

4.4.11. Chloride [Fig.-11, Tab.-1]

The maximum value of chloride was recorded as 125 mg.L^{-1} at station-1 during the period of pre-monsoon and the minimum value was 80 mg.L^{-1} at station-5 during the periods of monsoon and post-monsoon. The values of chloride were always higher at station-1 than the other stations (2, 3, 4 and 5) in the present investigation. Islam (1993) also recorded similar



observation during his study on the influence of effluents on the physico-chemical parameters of the Karnafully river discharged from the KPRC. The present investigation coincides with the work of Islam (1993).

Bhouyain (1979), Andrews *et. al.*, (1972) and APHA (1976) stated that industrial effluent contained high concentration of chloride that could be increased the water body where the effluent was being discharged. Islam (1993) recorded the similar results, which are well agreement with the present investigation.

The standard value of chloride for industrial effluents of EQS for Bangladesh (1991) was 600 mg.L⁻¹. In the present investigation the values of chloride at all stations were within the EQS Limit. So the values of chloride of the effluents from the KNM were not harmful for the water as well as for the biota of Khulna Bhairab river.

4.5. CONCLUSION

The investigation was carried out to evaluate the physico-chemical status of the Bhairab river water and the industrial effluents of the Khulna Newsprint Mills. Five sampling stations were selected on the basis of different sources of pollution. Paper mill wastes contained lignin, caustic soda, sodium sulfate, alum, dyes and significant quantity of wood fibers. They possess some problems such as depletion of dissolved oxygen, deposition of large amount of wood pulp on the bank of the river; destruction of aquatic life, water impaired with undesirable color and odor due to purification of organic matter.

It was observed that temperature of the river water varied between 24 to 32°C. The discharged of color effluents (as black liquor) to the river water was found to hamper the normal penetration of the sunlight affecting adversely the distribution of aquatic plants and phytoplanktonic organisms.

BOD values were high at the station-1 (grinding sieving drain water), 2 (grinding reject drain water), 3 (mixing of the river water) due to free CO₂ present, which consumed all the oxygen and caused CO₂ formation due to respiratory activity. Higher chloride concentration also showed due to respiratory sewage and caustic lime that was used in bleaching process in the Newsprint paper mills Ltd. High concentration of chlorides indicated the high pollution level which has adverse effect on the aquatic system and a rapid depletion of dissolved oxygen has been observed on the adjacent water body with a high value of BOD.

Among the five stations, the station-1 and 2 was much higher than the EQS value all the periods. The effluents of the Khulna Newsprint Mills were not maintained than the EQS value. The values of the E.C, TSS, TDS and total alkalinity were exceeded the EQS values and USPH standard values of the drinking water.

From the result, it has found that the pollution level of the river water was not much in the monsoon, as the dilution was high due to floods level and addition of water of different sources. The values of pH, DO, BOD, chloride, SS and other parameters were comparatively normal during the rainy season. The major factor responsible for self-purification in monsoon season is enough supply of oxygen because of higher rate of re-aeration. Due to heavy mixing of effluents and domestic sewage, it was noticed that the physico-chemical and biological balances of the river Bhairab were disturbed at the adjacent area.

CHAPTER FIVE

TRACE METALS IN WATER

5.1. INTRODUCTION

Water pollution with industrial effluents provides one of the classic examples of diseconomies of scale accompanying with the increase of industries in respect of environmental alteration. If few industries establish along a large river and discharge their effluents directly or indirectly into the river, natural purification may occur. But if the number increases, the effluent-degrading ability of the river becomes overstrained. As industries grow, so does the need for increased effluent discharge, which results in a heavier water-borne load of industrial wastes and effluents (Rahman, 1994).

The extent of industrial development in Bangladesh is still not very sizable and its rate is quite slow. In Bangladesh whatever the industries in existence are hardly equipped with any treatment plant to neutralize the effluents and solid wastes before discharge. As a result, waste disposal already seriously threatens the environment particularly the riverine environment. If the untreated effluent of any industry (especially Pulp and Paper Mills) alters the quality of water of the receiving water body, its effect is far reaching in the ecosystem as a whole (Chowdury, 1994).

However, fishes, shellfishes and other aquatic organisms inhabiting in the rivers, canals, etc. are not free from contaminants coming from industries and other sources. Although no study on the industrial waste management of the country is available till date, but it is true that every year huge amount of untreated toxic chemical waste products etc. from several chemicals and other industries of the country are released into the rivers, canals, and drains. Many heavy metals are normally present in the water body as trace elements. The natural concentration of Mercury, Lead, Zinc, Cadmium, Copper and Iron lie in an order of magnitude between about 10^{-5} and 10^{-8} mg.L⁻¹. These trace elements in low concentrations

play a significant role in construction of animal and plant cells. On the other hand, the concentrations in high doses play physiological process of both the plant and animal. Heavy metals can be highly concentrated in organisms belonging to the food chain, thereby having a highly toxic influence on the ecosystem (Rahman, 1994).

Continuous discharge of untreated industrial wastes into the aquatic environment endangers the safety of aquatic life and can reach the human body through the food chain. The effects of trace metal on aquatic system have been studied extensively as a result of wide spread contamination by organic and inorganic metallic species from industrial processes. Unambiguous findings of the effects of trace metal potential on the biota of aquatic system are rare, however, as confounding factors are often present. In attempting to quantify metal pollution, studies on the effects of metal pollutants are often hampered by the presence of more than metallic element and the variable toxicity of wastewater caused by changes of molecular form (Rahman, 1994).

However, the total concentrations of Fe, Cu, Cd, Mn, Pb, Cr, Co & Ni from surface water were analyzed seasonally to evaluate the total concentrations of those metals as mentioned from the Bhairab river at the vicinity of Khulna Newsprint Mills and Hardboard Mills.



5.2. MATERIALS AND METHODS

5.2.1. Collection of water samples

Water samples were collected from different stations as mentioned in chapter two. The samples were collected with the help of one litre polythene bottles that were previously soaked with a mixture of de-ionized water (975ml), 2% concentrated HNO_3 (20ml) and 0.5% H_2O_2 (5ml) for 24hours. On the next day, these bottles were scrupulously washed several times with de-ionized water, rinsed with double de-ionized water and then kept in an oven (65°C). The bottles were then ready for sample collection.

The entire beaker, container, volumetric flask etc. sampling water bottles were preserved soaking overnight with 20% HNO_3 and washed thoroughly and rinsed thrice with de-ionized water.

5.2.2. Preservation of the samples

To avoid bacterial degradation, the collected samples were mixed with conc. HNO_3 (3.5-4ml), slakened homogeneously and then carefully preserved in a refrigerator at 4°C thermostatic before laboratory analysis.

5.2.3 Laboratory Analysis

Laboratory analyses were carried out at Chemistry Division, Atomic Energy Center, Dhaka.

5.2.4. Estimation of Fe, Cu, Cd, Mn, Pb, Co, Ni and Cr

5.2.4.1. Preparation of Samples

200ml of water samples were kept in a Pyrex (250ml) beaker and evaporated the samples on water bath (temp. above 100°C) to about a dryness.

5.2.4.2. Digestion of Samples

1 ml Analar grade conc. HNO_3 were added in each beaker and digested on water bath (temperature above 100°C) placing watch glass on each beaker.

Blank digestions were also performed to quantify possible contamination.

After completed the digestion about 5 ml de-ionized water added in each beaker and warmed on a water bath (100°C) for few minutes. The beakers were then set aside to cool the solution. Then the digested samples along with the blank filtered by using filter paper (Quantitative Whatman No-41) and made the filtrate to 10 ml with de-ionized water in a 10 ml volumetric flask. Before volume up to the mark few drops of conc. HNO_3 were added in each flask.

Prior to analysis of different trace metals several dilutions were made.

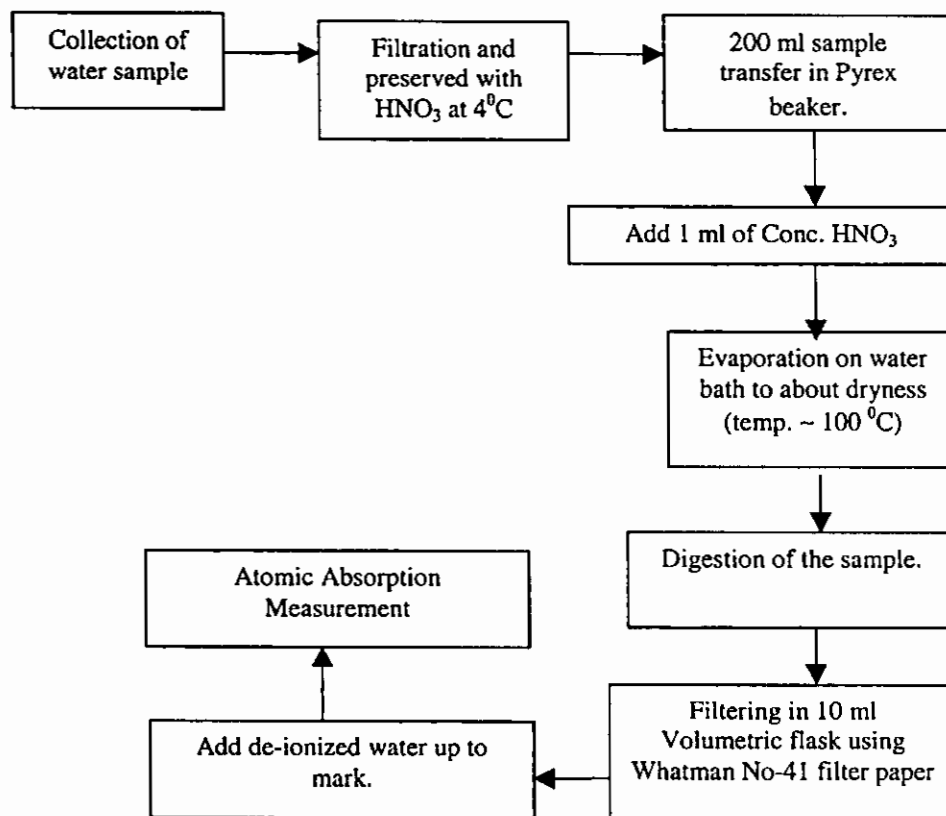


Fig.12 Flow chart for the detection of trace metal concentration in water sample by AAS (Atomic Absorption Spectrophotometer)

5.2.4.3. Atomic Absorption Spectrometric Measurements

The digested samples were then analyzed using air acetylene flame with combination as well as single element hollow cathode lamps and a Perkin Elmer 3110 Atomic Absorption Spectrometer at Atomic Energy Center, Dhaka.

5.2.4.4. Preparation of Standard Solutions

The standard solution of the elements Fe, Cu, Pb, Cd, Cr, Mn, Ni, and Co was prepared by pipetting the required amount of the solution from the stock solution which was from "Fisher Scientific Company, Chemical manufacturing, Fair Lawn, New Jersey, 07410, USA". The standard solution was prepared before every determination of the analytes of the present work..

5.2.4.5. Preparation of Calibration Curve

Before dealing with experimental details of atomic absorption spectrophotometric determinations, it is necessary to consider the mode of treatment of the experimental data obtained. To convert the measured absorption values into the concentration of the substance being determined, it is necessary to make use of a calibration curve.

A calibration curve for using in atomic absorption measurement was plotted by aspirating into the flame samples of solutions containing known concentration of the element to be determined and by measuring the absorption of each solution a graph was constructed. For the calibration curve the standard solution was prepared with the concentration. So that they covers the optimum absorbance range, in common with all absorbance measurements the reading was taken after the instrumental ZERO has been adjusted. At last three or more separate absorption reading was made with each solution and an average value was taken. For necessary condition the test solution was suitably diluted using a pipette and a volumetric flask. So that it gave absorbance reading in the desired range. Using the calibration curve it is simple matter to interpolate from the measured absorbance of the test solution, the concentration of the relevant element in the solution. The working graph was checked occasionally by making measurements with the standard solution if necessary a new calibration curve was drawn.

Analytical Procedures for Fe, Cu, Pb, Cd, Cr, Mn, Ni and Co
(Atomic Absorption Spectrophotometric Measurements)

Atomic number	Name of the elements	Name of the instruments	Model of instrument	Wave length (nm)	Silt setting	Light source	MDL (ppm)	Flame type
26	Fe	Perkin Elmer	3110	248.3	0.2	Hollow cathode lamp	0.000280	Air-acetylene flame, oxidizing (lean, blue)
29	Cu	Perkin Elmer	3110	324.8	0.7	Hollow cathode lamp	0.000180	Air-acetylene flame, oxidizing (lean, blue)
48	Cd	Perkin Elmer	3110	228.8	0.7	Hollow cathode lamp	0.001120	Air-acetylene flame, oxidizing (lean, blue)
25	Mn	Perkin Elmer	3110	279.5	0.2	Hollow cathode lamp	0.000256	Air-acetylene flame, oxidizing (lean, blue)
82	Pb	Perkin Elmer	3110	283.3	0.7	Hollow cathode lamp	0.000028	Air-acetylene flame, oxidizing (lean, blue)
24	Cr	Perkin Elmer	3110	357.9	0.7	Hollow cathode lamp	0.000104	Air-acetylene flame, oxidizing (lean, blue)
27	Co	Perkin Elmer	3110	240.7	-	Hollow cathode lamp	-	Air-acetylene flame, oxidizing (lean, blue)
28	Ni	Perkin Elmer	3110	232	0.2	Hollow cathode lamp	-	Air-acetylene flame, oxidizing (lean, blue)

5.3. RESULTS

5.3.1. Concentration of trace metals in water at station-1 [Fig.-13 Tab. 2, 3]

Iron (Fe)

The concentrations of Fe at station-1 ranged from $93.2\mu\text{g.L}^{-1}$ to $312\mu\text{g.L}^{-1}$. The maximum concentration as observed ($312\mu\text{g.L}^{-1}$) during the period of pre-monsoon and the minimum concentration was observed ($93.2\mu\text{g.L}^{-1}$) during the period of monsoon.

After pre-monsoon the value of Fe suddenly dropped to $93.2\mu\text{g.L}^{-1}$ at station-1.

Copper (Cu)

The connection of Cu at station-1 ranged from $5.20\mu\text{g.L}^{-1}$ to $7.50\mu\text{g.L}^{-1}$. The maximum ($7.50\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon and the minimum ($5.50\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. The concentration of Cu were more or less similar at station-1.

Cadmium (Cd)

The concentration of Cd at station-1 ranged $<2.08\mu\text{g.L}^{-1}$. All the season the concentration level was below the $<2.08\mu\text{g.L}^{-1}$. The concentration of Cd were more or less similar at station-1.

Manganese (Mn)

The connection of Mn at station-1 ranged from $33.75\mu\text{g.L}^{-1}$ to $62\mu\text{g.L}^{-1}$. The maximum ($62\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon and the minimum ($33.75\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. Abrupt changes in fluctuation were occurred among the three seasons.

Lead (Pb)

The concentration of Pb at station-1 ranged between $6.66\mu\text{g.L}^{-1}$ and $8.21\mu\text{g.L}^{-1}$. The maximum ($8.21\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon and the minimum ($6.66\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. The concentration of Pb were more or less similar at station-1.

Chromium (Cr)

The concentrations of Cr at station-1 ranged $<14.7\mu\text{g.L}^{-1}$. All the seasons the concentration level below the $<14.7\mu\text{g.L}^{-1}$. Among the three seasons the concentration of Cr were more or less similar at station-1.

Cobalt (Co)

The concentrations of Co at station-1 ranged from $2.11\mu\text{g.L}^{-1}$ to $<2.11\mu\text{g.L}^{-1}$. The maximum ($2.11\mu\text{g.L}^{-1}$) observed during the period of pre-monsoon and the minimum ($<2.11\mu\text{g.L}^{-1}$) concentrations of Co was observed during the period of post-monsoon & Monsoon.

Nickel (Ni)

The concentration of Ni at station-1 ranged from $4.73\mu\text{g.L}^{-1}$ to $11.06\mu\text{g.L}^{-1}$. The highest value ($11.06\mu\text{g.L}^{-1}$) was observed during the period of pre-monsoon at the lowest value ($4.73\mu\text{g.L}^{-1}$) was observed during the period of monsoon. After the period of pre-monsoon, the Ni concentration of suddenly dropped. The value of (Ni) suddenly dropped to $4.73\mu\text{g.L}^{-1}$ at station-1.

5.3.2 Concentration of trace metals in water at station-2 [Fig.- 14 Tab.- 2, 4]

Iron (Fe)

The concentration of Fe at station-2 ranged from $62.52\mu\text{g.L}^{-1}$ to $2341\mu\text{g.L}^{-1}$. The maximum ($2341\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon and the minimum ($62.52\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. After pre-monsoon the value of Fe was suddenly dropped to $62.52\mu\text{g.L}^{-1}$ at station-2.

Copper (Cu)

The concentration of Cu at station-2 ranged from $2.00\mu\text{g.L}^{-1}$ to $11.2\mu\text{g.L}^{-1}$. The maximum ($11.2\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon and the minimum ($2.00\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon. After pre-monsoon the concentration of Cu was suddenly fluctuated at station-2.

Cadmium (Cd)

The concentration of Cd at station-2 ranged $<2.08\mu\text{g.L}^{-1}$ to $15.52\mu\text{g.L}^{-1}$. The maximum ($15.2\mu\text{g.L}^{-1}$) Concentration was observed during the period of monsoon and the minimum ($<2.08\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon and post-monsoon respectively.

Manganese (Mn)

The concentration of Mn at station-2 fluctuated from $34.25\mu\text{g.L}^{-1}$ to $144\mu\text{g.L}^{-1}$. The highest value ($144\mu\text{g.L}^{-1}$) was observed during the period of pre-monsoon and the lowest value ($34.25\mu\text{g.L}^{-1}$) was during the period of monsoon. The variations of manganese concentration in water were not regular pattern.

Lead (Pb)

The concentrations of Pb at station-2 ranged between $8.21\mu\text{g.L}^{-1}$ and $70.7\mu\text{g.L}^{-1}$. The maximum ($70.7\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon and the minimum ($8.21\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon. The value of the pre-monsoon and post-monsoon were more or less similar. During the monsoon period, the value of Pb concentration was increased at station-2.

Chromium (Cr)

The concentration of Cr at station-2 ranged between $<14.7\mu\text{g.L}^{-1}$ and $61.3\mu\text{g.L}^{-1}$. The maximum ($61.3\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon and the minimum ($<14.7\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon. The value of Cr concentration was increased in the monsoon period.

Cobalt (Co)

The concentrations of Co at station-2 ranged from $4.22\mu\text{g.L}^{-1}$ to $42.18\mu\text{g.L}^{-1}$. The maximum ($42.18\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon and the minimum ($4.22\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon. During the period of pre-monsoon and post-monsoon were similar. After the pre-monsoon period, the value of Co concentration was increased.

Nickel (Ni)

The concentration of Ni at station-2 ranged from $5.32\mu\text{g.L}^{-1}$ to $64.74\mu\text{g.L}^{-1}$. The highest value ($64.74\mu\text{g.L}^{-1}$) was observed during the period of monsoon and the lowest value ($5.32\mu\text{g.L}^{-1}$) was observed during the period of post-monsoon. After the pre-monsoon period, the value of (Ni) was suddenly increased.

5.3.3 Concentration of trace metals in water at station-3 [Fig.- 15 Tab.-2, 5]

Iron (Fe)

The concentrations of Fe at station-3 ranged from $132\mu\text{g.L}^{-1}$ to $2175\mu\text{g.L}^{-1}$. The maximum concentration as observed ($2175\mu\text{g.L}^{-1}$) during the period of pre-monsoon and the minimum concentration was observed ($133\mu\text{g.L}^{-1}$) during the period of monsoon.

The value of Fe was fluctuated at the station-3

Copper (Cu)

The connection of Cu at station-3 ranged from $3.50\mu\text{g.L}^{-1}$ to $5.46\mu\text{g.L}^{-1}$. The maximum ($5.46\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon and the minimum ($3.50\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon. Among the three seasons, the values of Cu concentrations were more or less similar.

Cadmium (Cd)

The concentration of Cd at station-3 ranged $<2.08\mu\text{g.L}^{-1}$. All the season the concentration level was below the $<2.08\mu\text{g.L}^{-1}$. The concentration of Cd were more or less similar at station-3.

Manganese (Mn)

The connection of Mn at station-3 ranged from $34.37\mu\text{g.L}^{-1}$ to $93.0\mu\text{g.L}^{-1}$. The maximum ($93.0\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon and the minimum ($34.37\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. The values of manganese were not regular pattern.

Lead (Pb)

The concentration of Pb at station-3 ranged between $<5.47\mu\text{g.L}^{-1}$ to $6.84\mu\text{g.L}^{-1}$. The maximum ($6.84\mu\text{g.L}^{-1}$) concentration were observed during the period of post-monsoon and the minimum ($<5.47\mu\text{g.L}^{-1}$) concentration was observed during the pre-monsoon. The concentration of Pb were more or less similar at station-3.

Chromium (Cr)

The concentrations of Cr at station-3 ranged $<14.7\mu\text{g.L}^{-1}$. All the seasons the concentration level below the $<14.7\mu\text{g.L}^{-1}$. Among the three seasons the concentration of Cr were more or less similar at station-3.

Cobalt (Co)

The concentrations of Co at station-3 ranged from $4.22\mu\text{g.L}^{-1}$ to $5.22\mu\text{g.L}^{-1}$. The maximum ($5.28\mu\text{g.L}^{-1}$) observed during the period of pre-monsoon and the minimum ($4.22\mu\text{g.L}^{-1}$) concentrations of Co was observed during the period of post-monsoon. During the period of pre-monsoon, the value of Ni concentration was not detected.

Nickel (Ni)

The concentration of Ni at station-3 ranged $<2.46\mu\text{g.L}^{-1}$. All the season the concentration level was below the $<2.46\mu\text{g.L}^{-1}$. The concentration of Ni were more or less similar at station-3.

5.3.4 Concentration of trace metals in water at station-4 [Fig.- 16 Tab.- 2, 6]

Iron (Fe)

The concentration of Fe at station-4 ranged from $342\mu\text{g.L}^{-1}$ to $2756\mu\text{g.L}^{-1}$. The maximum ($2756\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon and the minimum ($342\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon.

The value of Fe was suddenly variable at station-4.

Copper (Cu)

The concentration of Cu at station-4 ranged from $5.5\mu\text{g.L}^{-1}$ to $7.03\mu\text{g.L}^{-1}$. The maximum ($7.03\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon and the minimum ($5.5\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon. Among the three seasons, the values of Cu concentration were more or less similar.

Cadmium (Cd)

The concentration of Cd at station-4 ranged $<2.08\mu\text{g.L}^{-1}$. All the season the concentration level was below the $<2.08\mu\text{g.L}^{-1}$. The concentration of Cd were more or less similar at station-4.

Manganese (Mn)

The concentration of Mn at station-4 ranged from $42.37\mu\text{g.L}^{-1}$ to $168\mu\text{g.L}^{-1}$. The highest value $168\mu\text{g.L}^{-1}$ observed during the period of pre-monsoon and the lowest value $42.37\mu\text{g.L}^{-1}$ during the period of monsoon. Abrupt changes in fluctuation were occurred among the three seasons.

Lead (Pb)

The concentrations of Pb at station-4 ranged between $6.84\mu\text{g.L}^{-1}$ to $8.21\mu\text{g.L}^{-1}$. The maximum ($8.21\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon and the minimum ($6.84\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon. Among the three seasons the value of Pb were more or similar at station-4.

Chromium (Cr)

The concentration of Cr at station-4 ranged between $<14.7\mu\text{g.L}^{-1}$ to $14.7\mu\text{g.L}^{-1}$. The maximum ($14.7\mu\text{g.L}^{-1}$) concentration was observed during the period of pe-monsoon and the minimum ($<14.7\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon. During the period of monsoon, the concentrations of Cr were more or less similar.

Cobalt (Co)

The concentrations of Co at station-4 ranged from $<2.11\mu\text{g.L}^{-1}$. All the season the concentration level was below the $<2.11\mu\text{g.L}^{-1}$. The concentration of Co were more or less similar at station-4.

Nickel (Ni)

The concentration of Ni at station-4 ranged from $<2.46\mu\text{g.L}^{-1}$ to $5.73\mu\text{g.L}^{-1}$. The highest value ($5.73\mu\text{g.L}^{-1}$) was observed during the period of pre-monsoon and the lowest value ($4.91\mu\text{g.L}^{-1}$) was observed during the period of post-monsoon. The value of (Ni) were more or less similar at station-4.

5.3.5 Concentration of trace metals in water at station-5 [Fig.- 17 Tab.-2, 7]

Iron (Fe)

The concentrations of Fe at station-5 ranged from $187\mu\text{g.L}^{-1}$ to $1693\mu\text{g.L}^{-1}$. The maximum concentration as observed ($1693\mu\text{g.L}^{-1}$) during the period of pre-monsoon and the minimum concentration was observed ($187\mu\text{g.L}^{-1}$) during the period of monsoon.

The value of Fe was suddenly dropped at the station-5.

Copper (Cu)

The connection of Cu at station-5 ranged from $6.51\mu\text{g.L}^{-1}$ to $16.0\mu\text{g.L}^{-1}$. The maximum ($16.0\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon and the minimum ($6.51\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. The concentration of Cu was dropped during the period of monsoon at station-5.

Cadmium (Cd)

The concentration of Cd at station-5 ranged $<2.08\mu\text{g.L}^{-1}$. All the season the concentration level was below the $<2.08\mu\text{g.L}^{-1}$. The concentration of Cd were more or less similar at station-5.

Manganese (Mn)

The connection of Mn at station-5 ranged from $48\mu\text{g.L}^{-1}$ to $89.5\mu\text{g.L}^{-1}$. The highest value ($89.5\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon and the lowest value ($48\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. The values of manganese concentration were not regular pattern.

Lead (Pb)

The concentration of Pb at station-5 ranged between $<5.47\mu\text{g.L}^{-1}$ to $5.47\mu\text{g.L}^{-1}$. The maximum ($5.47\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon and the minimum ($<5.47\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon & monsoon. The concentration of Pb were more or less similar at station-5.

Chromium (Cr)

The concentrations of Cr at station-5 ranged $<14.7\mu\text{g.L}^{-1}$. All the seasons the concentration level below the $<14.7\mu\text{g.L}^{-1}$. Among the three seasons the concentration of Cr were more or less similar at station-5.

Cobalt (Co)

The concentrations of Co at station-5 ranged from $<2.11\mu\text{g.L}^{-1}$ to $3.52\mu\text{g.L}^{-1}$. The maximum ($3.52\mu\text{g.L}^{-1}$) observed during the period of pre-monsoon and the minimum ($<2.11\mu\text{g.L}^{-1}$) concentrations of Co was observed during the period of Monsoon.

Nickel (Ni)

The concentration of Ni at station-5 ranged from $4.73\mu\text{g.L}^{-1}$ to $6.14\mu\text{g.L}^{-1}$. The highest value ($6.14\mu\text{g.L}^{-1}$) was observed during the period of post-monsoon at the lowest value ($4.73\mu\text{g.L}^{-1}$) was observed during the period of monsoon. The concentrations of Ni were more or less similar at station-5.



5.3.6. Concentration of trace metals in water at station-6 [Fig.-18 Tab. 2, 8]

Iron (Fe)

The concentrations of Fe at station-6 ranged from $359\mu\text{g.L}^{-1}$ to $770\mu\text{g.L}^{-1}$. The maximum concentration as observed ($770\mu\text{g.L}^{-1}$) during the period of post-monsoon and the minimum concentration was observed ($359\mu\text{g.L}^{-1}$) during the period of monsoon. The value of Fe was suddenly dropped at stations-6.

Copper (Cu)

The connection of Cu at station-6 ranged from $4.94\mu\text{g.L}^{-1}$ to $6.0\mu\text{g.L}^{-1}$. The maximum ($6.0\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon and the minimum ($4.94\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. The concentration of Cu were more or less similar at station-6.

Cadmium (Cd)

The concentration of Cd at station-6 ranged $<2.08\mu\text{g.L}^{-1}$. All the season the concentration level was below the $<2.08\mu\text{g.L}^{-1}$. The concentration of Cd were more or less similar at station-6.

Manganese (Mn)

The connection of Mn at station-6 ranged from $7.25\mu\text{g.L}^{-1}$ to $36.12\mu\text{g.L}^{-1}$. The maximum ($36.12\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon and the minimum ($7.25\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon. The values of manganese were more or less similar during the period of pre-monsoon and post-monsoon.

Lead (Pb)

The concentration of Pb at station-6 ranged from $<5.47\mu\text{g.L}^{-1}$ to $5.47\mu\text{g.L}^{-1}$. The maximum ($5.47\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon and post-monsoon and the minimum ($<5.47\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon. The concentration of Pb were more or less similar at station-6.

Chromium (Cr)

The concentrations of Cr at station-6 ranged $<14.7\mu\text{g.L}^{-1}$. All the seasons the concentration level below the $<14.7\mu\text{g.L}^{-1}$. Among the three seasons the concentration of Cr were more or less similar at station-6.

Cobalt (Co)

The concentrations of Co at station-6 ranged from $<2.11\mu\text{g.L}^{-1}$ to $2.5\mu\text{g.L}^{-1}$. The maximum ($2.5\mu\text{g.L}^{-1}$) observed during the period of monsoon and the minimum ($<2.11\mu\text{g.L}^{-1}$) concentrations of Co was observed during the period of pre-monsoon.

Nickel (Ni)

The concentration of Ni at station-6 ranged from $<2.46\mu\text{g.L}^{-1}$ to $6.31\mu\text{g.L}^{-1}$. The highest value ($6.31\mu\text{g.L}^{-1}$) was observed during the period of monsoon at the lowest value ($<2.11\mu\text{g.L}^{-1}$) was observed during the period of pre-monsoon. The value of monsoon and post-monsoon were more or less similar.

5.3.7 Concentration of trace metals in water at station-7 [Fig.- 19 Tab.- 2, 9]

Iron (Fe)

The concentration of Fe at station-7 ranged from $664\mu\text{g.L}^{-1}$ to $936\mu\text{g.L}^{-1}$. The maximum ($936\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon and the minimum ($664\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. The value of Fe were more or less similar.

Copper (Cu)

The concentration of Cu at station-7 ranged from $6.51\mu\text{g.L}^{-1}$ to $8.25\mu\text{g.L}^{-1}$. The maximum ($8.25\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon and the minimum ($6.51\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. The concentrations of Cu were more or less similar at station-7.

Cadmium (Cd)

The concentration of Cd at station-7 ranged $<2.08\mu\text{g.L}^{-1}$. All the season the concentration level was below the $<2.08\mu\text{g.L}^{-1}$. The concentration of Cd were more or less similar at station-7.

Manganese (Mn)

The concentration of Mn at station-7 ranged from $10.5\mu\text{g.L}^{-1}$ to $35.5\mu\text{g.L}^{-1}$. The highest value ($35.5\mu\text{g.L}^{-1}$) was observed during the period of monsoon and the lowest value ($10.5\mu\text{g.L}^{-1}$) was during the period of pre-monsoon. The values of manganese were suddenly increased at station-7.

Lead (Pb)

The concentrations of Pb at station-7 ranged from $<5.47\mu\text{g.L}^{-1}$ to $6.66\mu\text{g.L}^{-1}$. The maximum ($6.66\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon and the minimum ($<5.47\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon. After the pre-monsoon the concentrations of Pb increased at station-7.

Chromium (Cr)

The concentrations of Cr at station-7 ranged $<14.7\mu\text{g.L}^{-1}$. All the seasons the concentration level below the $<14.7\mu\text{g.L}^{-1}$. Among the three seasons the concentration of Cr were more or less similar at station-7.

Cobalt (Co)

The concentrations of Co at station-7 ranged from $<2.11\mu\text{g.L}^{-1}$ to $4.57\mu\text{g.L}^{-1}$. The maximum ($4.57\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon and the minimum ($<2.11\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. After the pre-monsoon the concentration of Co were decreased at station-7.

Nickel (Ni)

The concentration of Ni at station-7 ranged from $4.73\mu\text{g.L}^{-1}$ to $7.37\mu\text{g.L}^{-1}$. The highest value ($7.37\mu\text{g.L}^{-1}$) was observed during the period of post-monsoon and the lowest value ($4.37\mu\text{g.L}^{-1}$) was observed during the period of monsoon. The values of nickel (Ni) were suddenly dropped at station-7.

5.3.8 Concentration of trace metals in water at station-8 [Fig.- 20 Tab.-2, 10]

Iron (Fe)

The concentrations of Fe at station-8 ranged from $773\mu\text{g.L}^{-1}$ to $1428\mu\text{g.L}^{-1}$. The maximum concentration as observed ($1428\mu\text{g.L}^{-1}$) during the period of pre-monsoon and the minimum concentration was observed ($773\mu\text{g.L}^{-1}$) during the period of monsoon.

The value of Fe suddenly dropped at the station-8.

Copper (Cu)

The concentration of Cu at station-8 ranged from $5.98\mu\text{g.L}^{-1}$ to $17.5\mu\text{g.L}^{-1}$. The maximum ($17.5\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon and the minimum ($5.98\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. The concentrations of Cu were more or less similar at station-8.

Cadmium (Cd)

The concentration of Cd at station-8 ranged $<2.08\mu\text{g.L}^{-1}$. All the season the concentration level was below the $<2.08\mu\text{g.L}^{-1}$. The concentration of Cd were more or less similar at station-8.

Manganese (Mn)

The concentration of Mn at station-8 ranged from $41.62\mu\text{g.L}^{-1}$ to $280\mu\text{g.L}^{-1}$. The highest value ($280\mu\text{g.L}^{-1}$) was observed during the period of pre-monsoon and the lowest value ($41.62\mu\text{g.L}^{-1}$) was during the period of monsoon. The values of manganese were suddenly dropped to $41.62\mu\text{g.L}^{-1}$ at station -8.

Lead (Pb)

The concentrations of Pb at station-8 ranged from $5.47\mu\text{g.L}^{-1}$ to $10.95\mu\text{g.L}^{-1}$. The maximum ($10.95\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon and the minimum ($5.47\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. After the pre-monsoon the concentrations of Pb was dropped.

Chromium (Cr)

The concentrations of Cr at station-8 ranged $<14.7\mu\text{g.L}^{-1}$. All the seasons the concentration level below the $<14.7\mu\text{g.L}^{-1}$. Among the three seasons the concentration of Cr were more or less similar at station-8.

Cobalt (Co)

The concentrations of Co at station-8 ranged from $<2.11\mu\text{g.L}^{-1}$ to $2.81\mu\text{g.L}^{-1}$. The maximum ($2.81\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon and the minimum ($<2.11\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. The concentrations of Co were more or less similar at station-8.

Nickel (Ni)

The concentration of Ni at station-8 ranged from $2.46\mu\text{g.L}^{-1}$ to $6.31\mu\text{g.L}^{-1}$. The highest value ($6.31\mu\text{g.L}^{-1}$) was observed during the period of monsoon and the lowest value ($2.46\mu\text{g.L}^{-1}$) was observed during the period of pre-monsoon.

5.3.9 Concentration of trace metals in water at station-9 [Fig.- 21 Tab.-2, 11]

Iron (Fe)

The concentrations of Fe at station-9 ranged from $964\mu\text{g.L}^{-1}$ and $1859\mu\text{g.L}^{-1}$. The maximum concentration as observed ($1859\mu\text{g.L}^{-1}$) during the period of pre-monsoon and the minimum concentration was observed ($964\mu\text{g.L}^{-1}$) during the period of monsoon.

The value of Fe suddenly dropped at the station-9.

Copper (Cu)

The concentration of Cu at station-9 ranged from $7.29\mu\text{g.L}^{-1}$ to $14.0\mu\text{g.L}^{-1}$. The maximum ($14.5\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon and the minimum ($7.29\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. The concentrations of Cu were suddenly dropped monsoon period.

Cadmium (Cd)

The concentration of Cd at station-9 ranged $<2.08\mu\text{g.L}^{-1}$. All the season the concentration level was below the $<2.08\mu\text{g.L}^{-1}$. The concentration of Cd were more or less similar at station-9.

Manganese (Mn)

The concentration of Mn at station-9 ranged from $55.25\mu\text{g.L}^{-1}$ to $237\mu\text{g.L}^{-1}$. The highest value ($237\mu\text{g.L}^{-1}$) was observed during the period of pre-monsoon and the lowest value ($55.25\mu\text{g.L}^{-1}$) was during the period of monsoon. The values of manganese were suddenly dropped to $55.25\mu\text{g.L}^{-1}$ at station -9.

Lead (Pb)

The concentrations of Pb at station-9 ranged from $6.66\mu\text{g.L}^{-1}$ to $10.95\mu\text{g.L}^{-1}$. The maximum ($10.95\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon and the minimum ($6.66\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. Among the three seasons the concentrations of Pb were more or less similar.

Chromium (Cr)

The concentrations of Cr at station-9 ranged $<14.7\mu\text{g.L}^{-1}$. All the seasons the concentration level below the $<14.7\mu\text{g.L}^{-1}$. Among the three seasons the concentration of Cr were more or less similar at station-9.

Cobalt (Co)

The concentrations of Co at station-9 ranged from $<2.11\mu\text{g.L}^{-1}$ to $2.81\mu\text{g.L}^{-1}$. The maximum ($2.81\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon and the minimum ($<2.11\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. The concentration of Co were more or less similar at station-9.

Nickel (Ni)

The concentration of Ni at station-9 ranged from $<2.46\mu\text{g.L}^{-1}$ and $7.37\mu\text{g.L}^{-1}$. The highest value ($7.37\mu\text{g.L}^{-1}$) was observed during the period of post-monsoon and the lowest value ($<2.46\mu\text{g.L}^{-1}$) was observed during the period of pre-monsoon. The value of nickel gradually increased at station-9.

5.3.10 Concentration of trace metals in water at station-10 [Fig.- 22 Tab.-2, 12]

Iron (Fe)

The concentrations of Fe at station-10 ranged from $1186\mu\text{g.L}^{-1}$ to $1727\mu\text{g.L}^{-1}$. The maximum concentration as observed ($1727\mu\text{g.L}^{-1}$) during the period of pre-monsoon and the minimum concentration was observed ($1186\mu\text{g.L}^{-1}$) during the period of monsoon.

The value of Fe suddenly dropped to $1186\mu\text{g.L}^{-1}$ monsoon at the station-10.

Copper (Cu)

The concentration of Cu at station-10 ranged from $8.0\mu\text{g.L}^{-1}$ to $66.14\mu\text{g.L}^{-1}$. The maximum ($66.14\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon and the minimum ($8.0\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon. After the concentrations of Cu suddenly increased during the period of monsoon.

Cadmium (Cd)

The concentration of Cd at station-10 ranged $<2.08\mu\text{g.L}^{-1}$. All the season the concentration level was below the $<2.08\mu\text{g.L}^{-1}$. The concentration of Cd were more or less similar at station-10.

Manganese (Mn)

The concentration of Mn at station-10 ranged from $385\mu\text{g.L}^{-1}$ to $724\mu\text{g.L}^{-1}$. The highest value ($724\mu\text{g.L}^{-1}$) was observed during the period of pre-monsoon and the lowest value ($385\mu\text{g.L}^{-1}$) was during the period of monsoon. The values of manganese suddenly dropped to during the period of post-monsoon.

Lead (Pb)

The concentrations of Pb at station-10 ranged from $13.33\mu\text{g.L}^{-1}$ to $20.53\mu\text{g.L}^{-1}$. The maximum ($20.53\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon and the minimum ($13.33\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. The concentrations of Pb were more or less similar at station-10.

Chromium (Cr)

The concentrations of Cr at station-10 ranged $<14.7\mu\text{g.L}^{-1}$. All the seasons the concentration level below the $<14.7\mu\text{g.L}^{-1}$. Among the three seasons the concentration of Cr were more or less similar at station-10.

Cobalt (Co)

The concentrations of Co at station-10 ranged from $2.11\mu\text{g.L}^{-1}$ to $2.5\mu\text{g.L}^{-1}$. The maximum ($2.5\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon and the minimum ($2.11\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon. The concentrations of Co were more or less similar at station-10.

Nickel (Ni)

The concentration of Ni at station-10 ranged from $9.01\mu\text{g.L}^{-1}$ to $12.63\mu\text{g.L}^{-1}$. The highest value ($12.63\mu\text{g.L}^{-1}$) was observed during the period of monsoon and the lowest value ($9.01\mu\text{g.L}^{-1}$) was observed during the period of post-monsoon.

5.3.11 Concentration of trace metals in water at station-11 [Fig.- 23 Tab.-2, 13]

Iron (Fe)

The concentrations of Fe at station-11 ranged from $1215\mu\text{g.L}^{-1}$ and $1351\mu\text{g.L}^{-1}$. The maximum concentration as observed ($1351\mu\text{g.L}^{-1}$) during the period of monsoon and the minimum concentration was observed ($1215\mu\text{g.L}^{-1}$) during the period of post-monsoon.

The concentration of Fe were more or less similar at station-11.

Copper (Cu)

The concentration of Cu at station-11 ranged from $12.0\mu\text{g.L}^{-1}$ to $22.39\mu\text{g.L}^{-1}$. The maximum ($22.39\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon and the minimum ($12.0\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon. The concentration of Cu was suddenly increased during the period of monsoon at station-11.

Cadmium (Cd)

The concentration of Cd at station-11 ranged $<2.08\mu\text{g.L}^{-1}$. All the season the concentration level was below the $<2.08\mu\text{g.L}^{-1}$. The concentration of Cd were more or less similar at station-11.

Manganese (Mn)

The concentration of Mn at station-11 ranged from $119\mu\text{g.L}^{-1}$ to $189\mu\text{g.L}^{-1}$. The highest value ($189\mu\text{g.L}^{-1}$) was observed during the period of monsoon and the lowest value ($119\mu\text{g.L}^{-1}$) was during the period of post-monsoon. The values of manganese suddenly increased during the period of monsoon at station-11.

Lead (Pb)

The concentrations of Pb at station-11 ranged from $8.21\mu\text{g.L}^{-1}$ to $13.33\mu\text{g.L}^{-1}$. The maximum ($13.33\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon and the minimum ($8.21\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon. Among the three seasons the concentrations of Pb were more or less similar at station-11.

Chromium (Cr)

The concentrations of Cr at station-11 ranged $<14.7\mu\text{g.L}^{-1}$. All the seasons the concentration level below the $<14.7\mu\text{g.L}^{-1}$. Among the three seasons the concentration of Cr were more or less similar at station-11.

Cobalt (Co)

The concentrations of Co at station-11 ranged from $2.5\mu\text{g.L}^{-1}$ to $3.52\mu\text{g.L}^{-1}$. The maximum ($3.52\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon and the minimum ($2.5\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. The concentrations of Co were more or less similar at station-11.

Nickel (Ni)

The concentration of Ni at station-11 ranged from $2.46\mu\text{g.L}^{-1}$ to $15\mu\text{g.L}^{-1}$. The highest value ($15\mu\text{g.L}^{-1}$) was observed during the period of monsoon and the lowest value ($2.46\mu\text{g.L}^{-1}$) was observed during the period of pre-monsoon. The value of nickel suddenly increased during the period of monsoon at station-11.



5.3.12 Concentration of trace metals in water at station-12 [Fig.- 24 Tab.-2, 14]

Iron (Fe)

The concentrations of Fe at station-12 ranged from $873\mu\text{g.L}^{-1}$ and $996\mu\text{g.L}^{-1}$. The maximum concentration as observed ($996\mu\text{g.L}^{-1}$) during the period of pre-monsoon and the minimum concentration was observed ($873\mu\text{g.L}^{-1}$) during the period of monsoon.

The value of Fe were more or less similar at station-12.

Copper (Cu)

The concentration of Cu at station-12 ranged from $10.0\mu\text{g.L}^{-1}$ to $17.75\mu\text{g.L}^{-1}$. The maximum ($17.75\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon and the minimum ($10.0\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon. The concentrations of Cu were more or less similar at station-12.

Cadmium (Cd)

The concentration of Cd at station-12 ranged $<2.08\mu\text{g.L}^{-1}$. All the season the concentration level was below the $<2.08\mu\text{g.L}^{-1}$. The concentration of Cd were more or less similar at station-12.

Manganese (Mn)

The concentration of Mn at station-12 ranged from $62.5\mu\text{g.L}^{-1}$ to $75.0\mu\text{g.L}^{-1}$. The highest value ($75.0\mu\text{g.L}^{-1}$) was observed during the period of post-monsoon and the lowest value ($62.5\mu\text{g.L}^{-1}$) was during the period of pre-monsoon. The values of manganese regular pattern at station-12.

Lead (Pb)

The concentrations of Pb at station-12 ranged from $5.47\mu\text{g.L}^{-1}$ to $10.95\mu\text{g.L}^{-1}$. The maximum ($10.95\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon and the minimum ($5.47\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon. The concentrations of Pb gradually increased at station-12.

Chromium (Cr)

The concentrations of Cr at station-12 ranged $<14.7\mu\text{g.L}^{-1}$. All the seasons the concentration level below the $<14.7\mu\text{g.L}^{-1}$. Among the three seasons the concentration of Cr were more or less similar at station-12.

Cobalt (Co)

The concentrations of Co at station-12 ranged from $<2.11\mu\text{g.L}^{-1}$. All the season the concentration level was below the $<2.11\mu\text{g.L}^{-1}$. The concentration of Co were more or less similar at station-12.

Nickel (Ni)

The concentration of Ni at station-12 ranged from $<2.46\mu\text{g.L}^{-1}$ to $4.09\mu\text{g.L}^{-1}$. The highest value ($4.09\mu\text{g.L}^{-1}$) was observed during the period of post-monsoon and the lowest value ($<2.46\mu\text{g.L}^{-1}$) was observed during the period of pre-monsoon. The value of Ni was increased during the period of post-monsoon at station-12.

5.3.13 Concentration of trace metals in water at station-13 [Fig.- 25 Tab.-2, 15]

Iron (Fe)

The concentrations of Fe at station-13 ranged from $67.8\mu\text{g.L}^{-1}$ and $372\mu\text{g.L}^{-1}$. The maximum concentration of iron ($372\mu\text{g.L}^{-1}$) observed during the period of post-monsoon and the minimum concentration was observed ($67.8\mu\text{g.L}^{-1}$) during the period of monsoon. After the pre-monsoon the value dropped during the period of monsoon.

Copper (Cu)

The concentration of Cu at station-13 ranged from $3.64\mu\text{g.L}^{-1}$ to $5.50\mu\text{g.L}^{-1}$. The maximum ($5.50\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon and the minimum ($3.64\mu\text{g.L}^{-1}$) concentration was observed during the period of monsoon. The concentrations of Cu were more or less similar at station-13.

Cadmium (Cd)

The concentration of Cd at station-13 ranged $<2.08\mu\text{g.L}^{-1}$. All the season the concentration level was below the $<2.08\mu\text{g.L}^{-1}$. The concentration of Cd were more or less similar at station-13.

Manganese (Mn)

The concentration of Mn at station-13 ranged from $9.5\mu\text{g.L}^{-1}$ to $11.0\mu\text{g.L}^{-1}$. The highest value ($11.0\mu\text{g.L}^{-1}$) was observed during the period of post-monsoon and the lowest value ($9.5\mu\text{g.L}^{-1}$) was during the period of monsoon. The concentrations of Mn were more or less similar at station-13.

Lead (Pb)

The concentrations of Pb at station-13 ranged from $<5.47\mu\text{g.L}^{-1}$ to $5.47\mu\text{g.L}^{-1}$. The maximum ($5.47\mu\text{g.L}^{-1}$) concentration was observed during the period of post-monsoon and the minimum ($<5.47\mu\text{g.L}^{-1}$) concentration was observed during the period of pre-monsoon and monsoon. The concentrations of Pb were more or less similar at station-13.

Chromium (Cr)

The concentrations of Cr at station-13 ranged $<14.7\mu\text{g.L}^{-1}$. All the seasons the concentration level below the $<14.7\mu\text{g.L}^{-1}$. Among the three seasons the concentration of Cr were more or less similar at station-13.

Cobalt (Co)

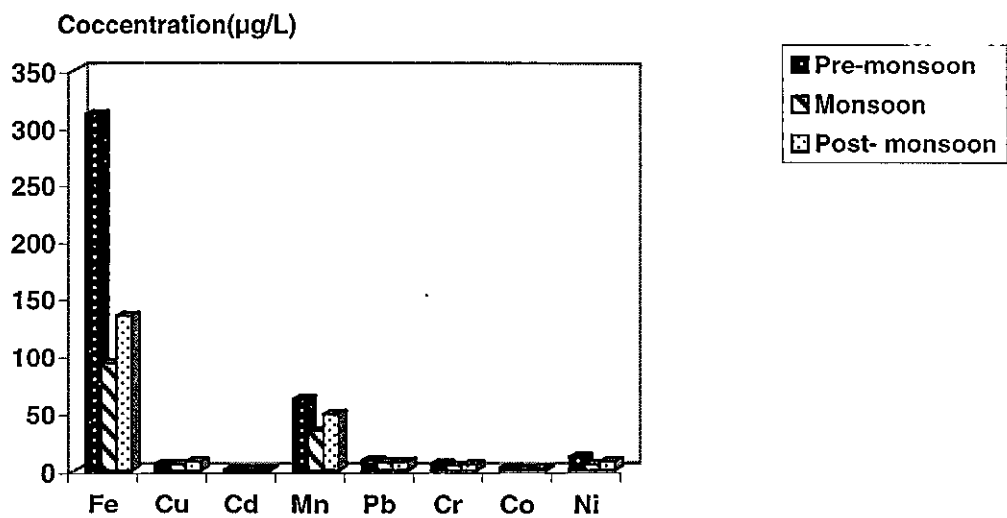
The concentrations of Co at station-13 ranged from $<2.11\mu\text{g.L}^{-1}$. All the season the concentration level was below the $<2.11\mu\text{g.L}^{-1}$. The concentration of Co were more or less similar at station-13.

Nickel (Ni)

The concentration of Ni at station-13 ranged from $3.94\mu\text{g.L}^{-1}$ to $6.55\mu\text{g.L}^{-1}$. The highest value ($6.55\mu\text{g.L}^{-1}$) was observed during the period of post-monsoon and the lowest value ($3.94\mu\text{g.L}^{-1}$) was observed during the period of monsoon. The concentrations of Ni were more or less similar at station-13.

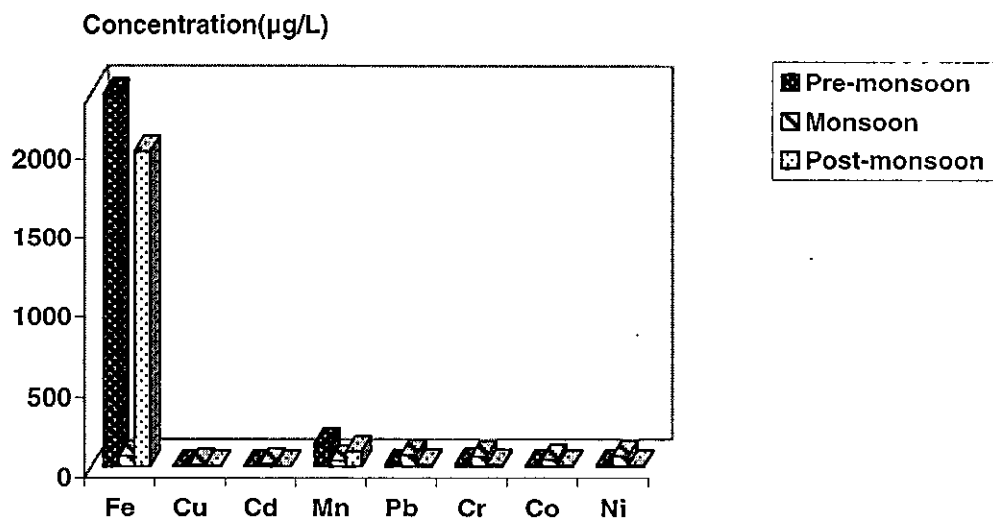
Table No.2 Seasonal Variation of Trace Metal Concentrations ($\mu\text{g.L}^{-1}$) in Water Samples of the Bhairab River in Different Stations.

No. of stations	Seasons	Metal Concentrations ($\mu\text{g.L}^{-1}$)							
		Fe	Cu	Cd	Mn	Pb	Cr	Co	Ni
Station 1	Pre-monsoon	312	5.50	<2.08	62.0	8.21	<14.7	2.11	11.06
	Monsoon	93.2	5.20	<2.08	33.75	6.66	<14.7	<2.11	4.73
	Post-monsoon	134	7.50	<2.08	49.25	6.84	<14.7	<2.11	7.37
Station 2	Pre-monsoon	2341	2.50	<2.08	144	8.21	14.7	4.22	6.14
	Monsoon	62.52	11.2	15.52	34.25	70.7	61.3	42.18	64.74
	Post-monsoon	1976	2.0	<2.08	93.75	9.58	<14.7	4.57	5.32
Station 3	Pre-monsoon	2175	3.50	<2.08	93.0	<5.47	<14.7	5.28	<2.46
	Monsoon	133	5.46	<2.08	34.37	5.47	<14.7	-	<2.46
	Post-monsoon	392	4.50	<2.08	52.25	6.84	<14.7	4.22	<2.46
Station 4	Pre-monsoon	2756	5.50	<2.08	168	6.84	14.7	<2.11	5.73
	Monsoon	342	7.03	<2.08	42.37	8.21	<14.7	<2.11	<2.46
	Post-monsoon	2497	6.50	<2.08	119	8.21	<14.7	<2.11	4.91
Station 5	Pre-monsoon	1693	16.0	<2.08	89.5	<5.47	<14.7	3.52	5.73
	Monsoon	187	6.51	<2.08	48.0	<5.47	<14.7	<2.11	4.73
	Post-monsoon	206	12.5	<2.08	63.75	5.47	<14.7	2.11	6.14
Station 6	Pre-monsoon	638	5.50	<2.08	7.25	<5.47	<14.7	<2.11	<2.46
	Monsoon	359	4.94	<2.08	36.12	5.47	<14.7	2.5	6.31
	Post-monsoon	770	6.0	<2.08	9.75	5.47	<14.7	2.11	4.91
Station 7	Pre-monsoon	823	8.0	<2.08	10.5	<5.47	<14.7	4.22	6.55
	Monsoon	664	6.51	<2.08	35.5	6.66	<14.7	<2.11	4.73
	Post-monsoon	936	8.25	<2.08	23.0	5.47	<14.7	4.57	7.37
Station 8	Pre-monsoon	1428	17.5	<2.08	280	10.95	<14.7	2.81	<2.46
	Monsoon	773	5.98	<2.08	41.62	5.47	<14.7	<2.11	6.31
	Post-monsoon	1235	12.5	<2.08	188	8.21	<14.7	2.11	4.91
Station 9	Pre-monsoon	1859	14.0	<2.08	237	10.95	<14.7	2.11	2.46
	Monsoon	964	7.29	<2.08	55.25	6.66	<14.7	<2.11	6.31
	Post-monsoon	1368	11.0	<2.08	194	8.21	<14.7	2.81	7.37
Station 10	Pre-monsoon	1727	8.0	<2.08	724	19.16	-	2.11	-
	Monsoon	1186	66.14	<2.08	385	13.33	<14.7	2.5	12.63
	Post-monsoon	1501	9.0	<2.08	525	20.53	<14.7	2.46	9.01
Station 11	Pre-monsoon	1295	12.0	<2.08	135	8.21	<14.7	2.81	2.46
	Monsoon	1351	22.39	<2.08	189	13.33	<14.7	2.5	15
	Post-monsoon	1215	15.0	<2.08	119	12.0	<14.7	3.52	3.27
Station 12	Pre-monsoon	996	10.0	<2.08	62.5	5.47	<14.7	<2.11	<2.46
	Monsoon	873	14.84	<2.08	65.5	8.20	<14.7	<2.11	3.15
	Post-monsoon	936	17.75	<2.08	75.0	10.95	<14.7	<2.11	4.09
Station 13	Pre-monsoon	325	5.00	<2.08	10.5	<5.47	<14.7	<2.11	5.73
	Monsoon	67.8	3.64	<2.08	9.50	<5.47	<14.7	<2.11	3.94
	Post-monsoon	372	5.50	<2.08	11.0	5.47	<14.7	<2.11	6.55



Trace Metals

Fig.-13 Seasonal variation of trace metal concentrations in surface water at station -1 (Grinding drain water)



Trace Metals

Fig.-14 Seasonal variation of trace metal concentrations in surface water at station -2 (Effluent of chemical drain water)

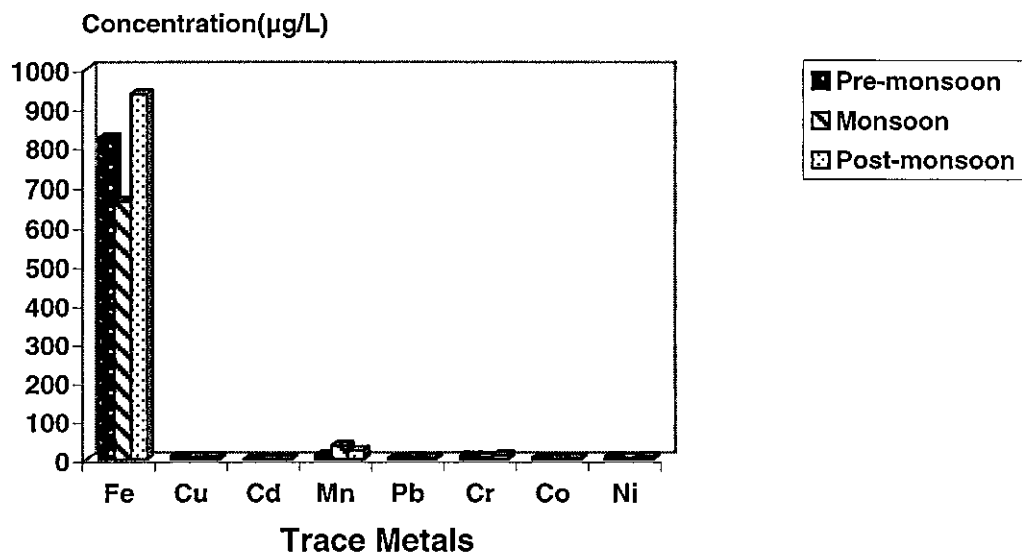


Fig.-19 Seasonal variation of trace metal concentrations in surface water samples at station-7 (100meters down of the Bhairab river)

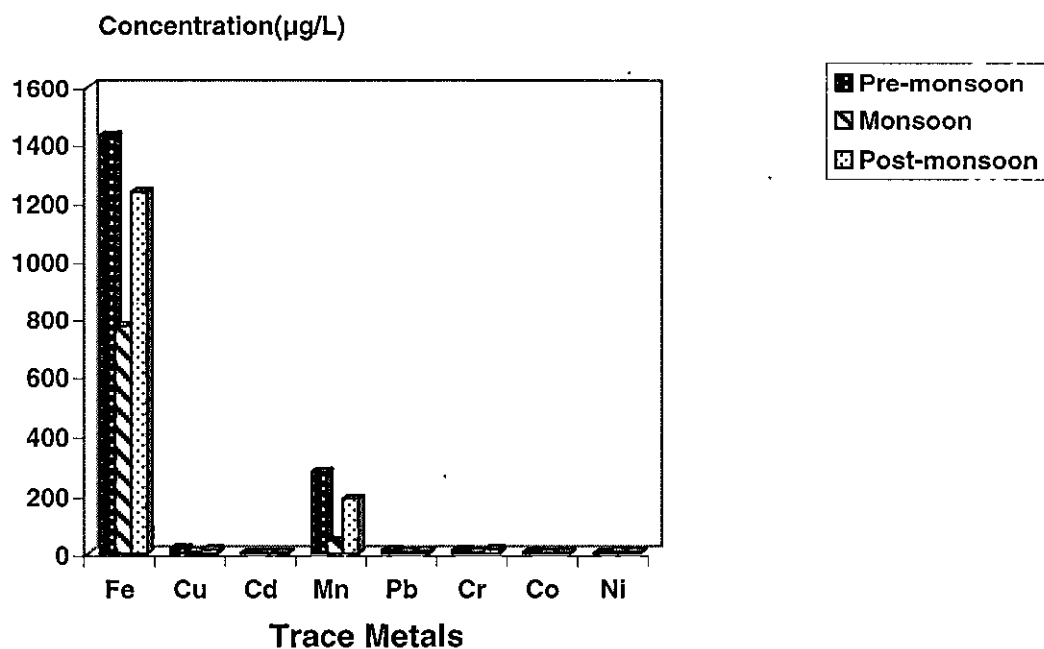
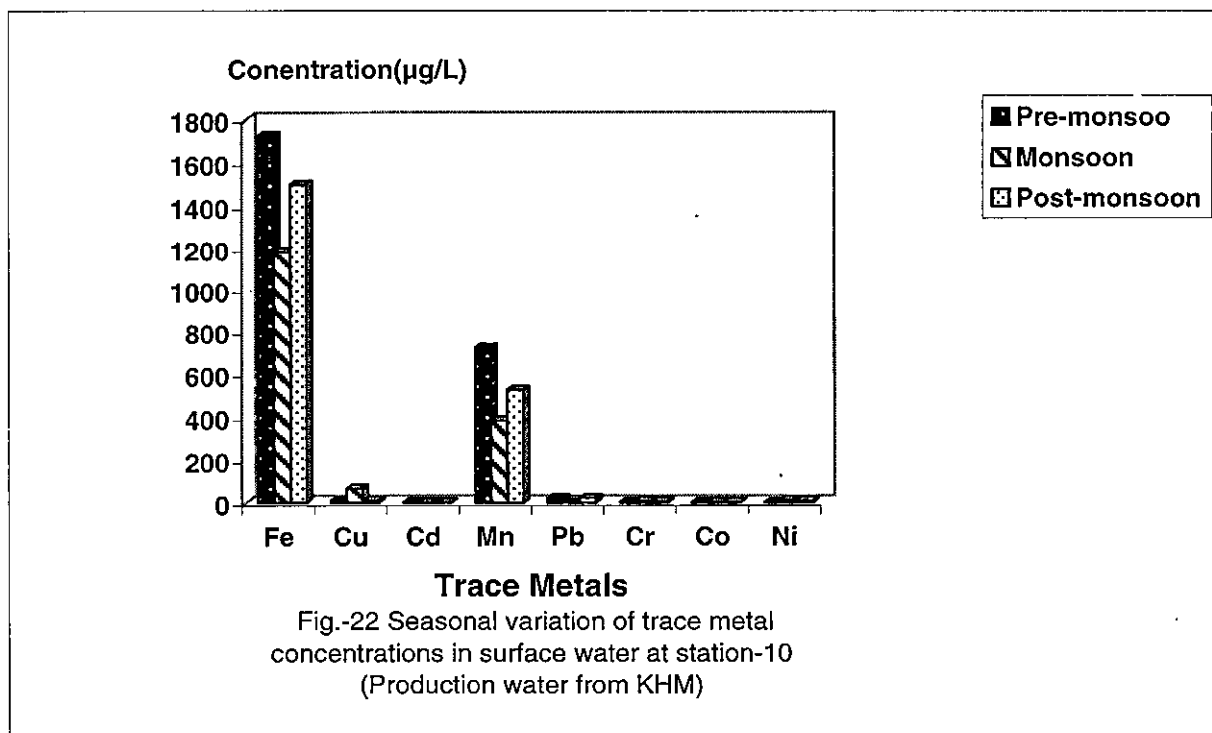
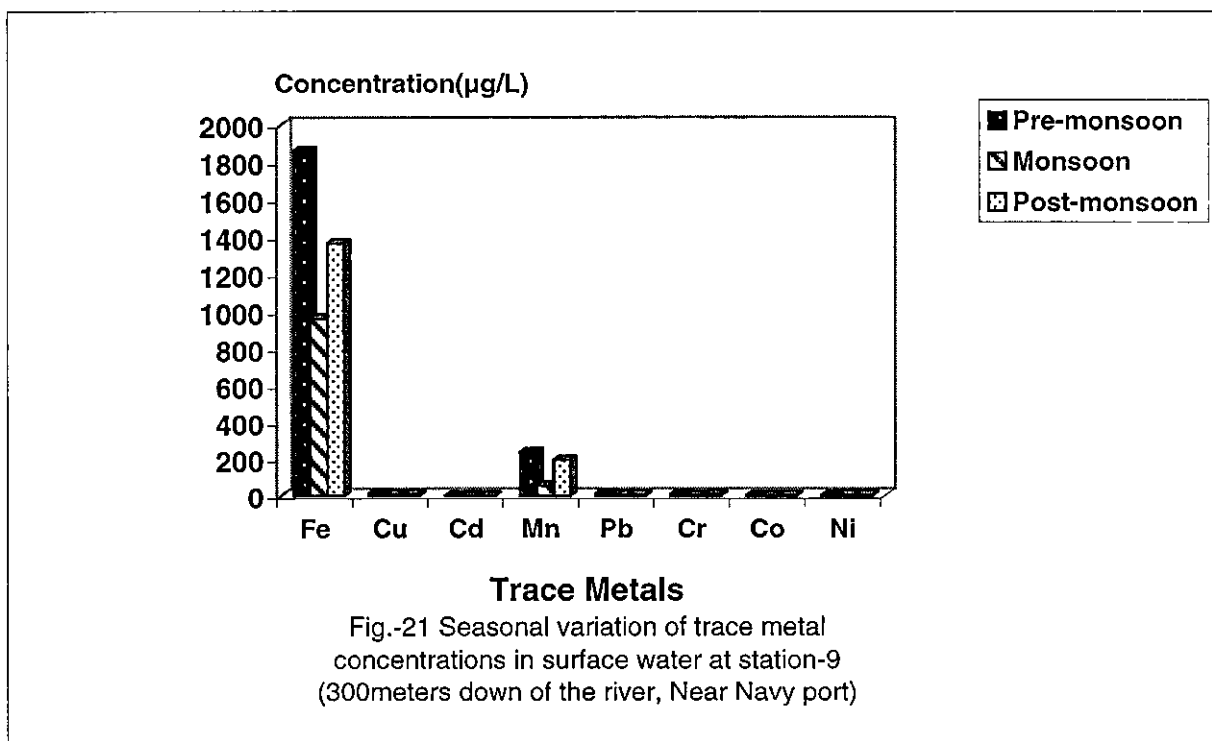


Fig.-20 Seasonal variation of trace metal concentrations in surface water at station-8 (200 meters down of the river)



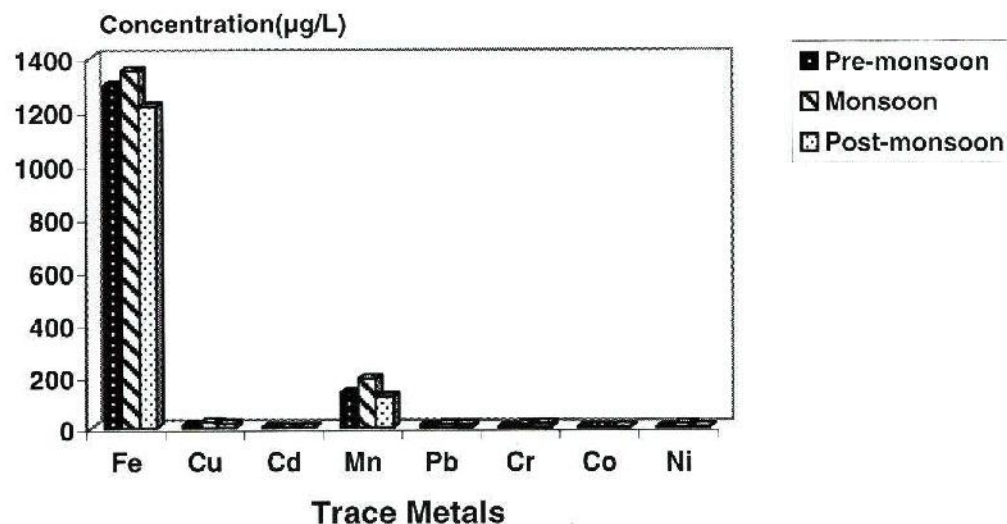


Fig.-23 Seasonal variation of trace metal concentrations in surface water at station-11 (Discharge water from KHM)

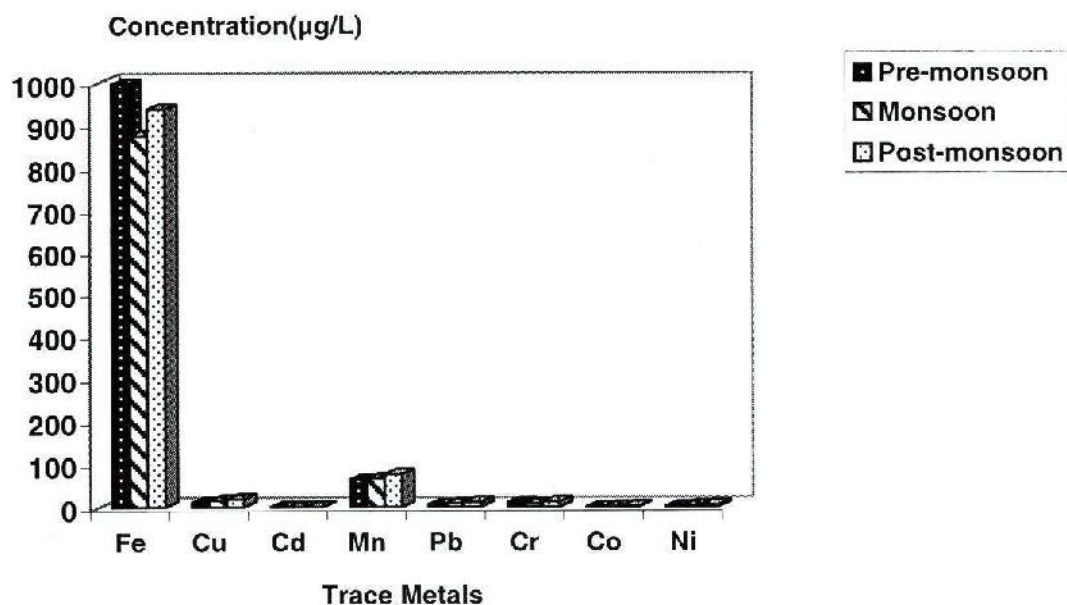


Fig.-24 Seasonal variation of trace metal concentrations in surface water at station-12 (Another discharge water from KHM)

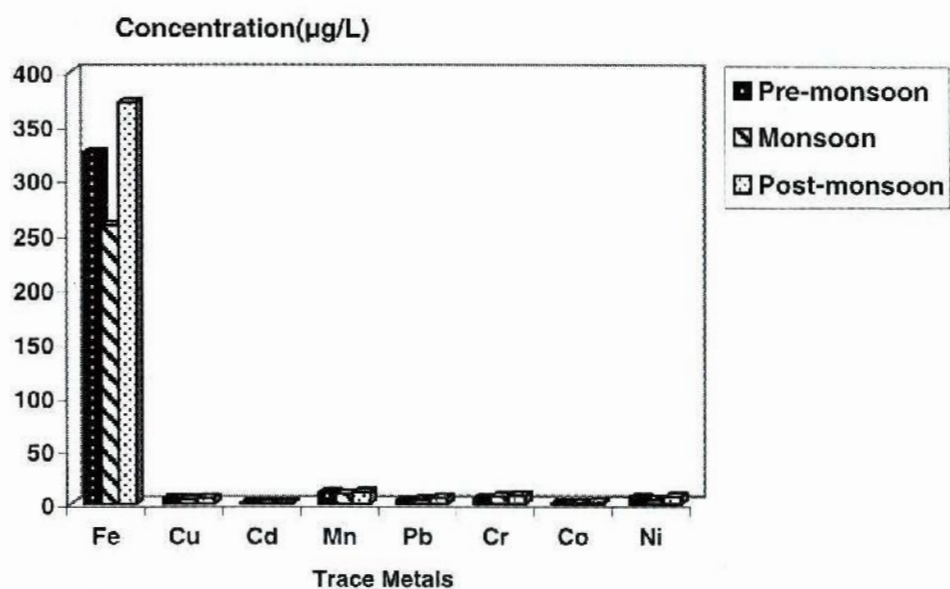


Fig.-25 Seasonal variation of trace metal concentrations in surface water at station-13
(35 miles up of the Bhairab river, Basundia, Jessore)



5.4. DISCUSSION

Considering the adverse pollution aspect of Bhairab River at the vicinity of Khulna Newsprint Mills (KNM) and Khulna Hardboard Mills (KHM) thirteen station were selected in the present study for the detection of trace metals in the water body of the Bhairab River. Water samples were collected seasonally from December 1998 to November 1999. The discharged effluents from KNM and KHM were responsible of carrying large amounts of waste containing high level of trace metals into the Bhairab River.

The maximum concentration of Fe was recorded as $2756\mu\text{g.L}^{-1}$ at station-4 (Discharged water of Khulna Newsprint Mills) during the period of pre-monsoon. The minimum concentration of Fe was $62.52\mu\text{g.L}^{-1}$ at station-2 (Chemical drain water of the KNM) during the period of monsoon. Zingde and Singbal (1983) worked on the characteristic of near shore water in the Binge Bay and had found at the level of 0.004 - 0.010 ppm ($4\text{-}10\mu\text{g.L}^{-1}$) of Fe. In the present investigation, even the lowest concentration ($62.52\mu\text{g.L}^{-1}$) of Fe was even higher than his highest concentration $10\mu\text{g.L}^{-1}$ studied by Zingde and Singbal. Qasim & Sen Gupta (1980) found the level of Fe in the range $6\text{-}66\mu\text{g.L}^{-1}$ in the Arabian Sea which was also lower in comparison with the present findings.

The concentration level of Fe was found to be higher at station 2, 3, 4, 5, 8, 9, 10 and 11 than the other stations 1, 6, 7, 12 and 13. These higher values of Fe might be due to the industrial effluents discharged from the KNM, KHM, and domestic sewage and shipping activities.

The maximum permissible value of Fe for industrial effluents of Environmental Quality Standard (EQS) for Bangladesh (1991) when discharge into surface water was 2ppm ($2000\mu\text{g.L}^{-1}$). In the present investigation, the highest concentration of Fe was $2756\mu\text{g.L}^{-1}$

and $2497\mu\text{g.L}^{-1}$ at station-4 (Discharge area of KNM) during the periods of pre-monsoon and post-monsoon were exceeded the (EQS, 1991) value and also exceeded the station-2 and 3 during the periods of pre-monsoon and post-monsoon. During the post-monsoon at station-2, pre-monsoon at station-5, pre and post-monsoon at station-10 were similar to the EQS values. These higher values of Fe were might be due to the industrial effluents discharged from KNM and KHM. The concentration of Fe was at station-8 during the period of pre-monsoon (200 meter down of the KNM) and station-9 during the period of pre-monsoon (300 meter down of the KNM near Navy port) closed to the EQS values. These higher values of Fe were might be extensive use of toxic agro-chemicals for the intensification of crops or shipping activities. So it was apprehended that the effluent of these industries require a pretreatment before discharge in the water body.

Ahmed (1997) found the maximum concentration of Fe was recorded as $3.460\mu\text{g.ml}^{-1}$ ($3460\mu\text{g.L}^{-1}$) and the minimum concentration of Fe was $0.121\mu\text{g.ml}^{-1}$ ($121\mu\text{g.L}^{-1}$). But the present findings of Fe concentration were lower than Ahmed (1997). Chowdhury (1994) studied on the Karnafully river and found maximum concentration of Fe was observed (effluent) 1.41ppm ($1410\mu\text{g.L}^{-1}$) and minimum 0.021ppm ($21\mu\text{g.L}^{-1}$) during the monsoon period. Khan and Hossain (1996) found the highest concentration of Fe was as $22.23\mu\text{g.ml}^{-1}$ ($22230\mu\text{g.L}^{-1}$) in the Karnafully estuary and the minimum concentration of Fe was as $1.10\mu\text{g.ml}^{-1}$ ($1100\mu\text{g.L}^{-1}$) in the Sandpit navigational route. The present work well agrees with the findings of Chowdhury (1994) and Ahmed (1997).

In present investigation the maximum concentration of Cu was recorded as $66.14\mu\text{g.L}^{-1}$ at station-10 (Production water of KHM) during the period of monsoon and the lowest concentration was $2.00\mu\text{g.L}^{-1}$ at station-2 during the period of post-monsoon. The concentration of Cu in surface water was much high at station-10 in monsoon period than the other stations. This high value of Cu in station-10 might be due to the incidental presence of suspended particulate matter with the effluents of the Khulna Hardboard Mills. In the present investigation seasonal variation of Cu concentration were minimum

in most stations which well agree with the findings of Khan and Hossain (1996); Khan and Rahman (1994); Khan and Mehadi (1994); Khan and Nath (1996).

George and Sawkar (1981) studied on organically associated Cu in Mandovi and Zuari estuaries and observed variations that were extractable. They stated that those variations were might be due to the super imposed effects of various factors such as adsorption or disruption by suspended particulate matter input by domestic wastes disposal in the river water. The present study well agrees with George and Sawkar. Kharkar *et.al.*, (1968) and Fukai *et.al.*, (1975) observed variations in Cu concentration during their studies due to the same causes. The present investigation correlates with the above authors.

ASTM (American Society for Testing and Materials, 1985) reported that Cu enters in water body through industrial effluents containing CuSO_4 used in metal plating and finishing operations. Abdullah and Royle (1974), Satynarayan *et.al.*, (1985), George (1986) and many others reported that the lower concentrations of Cu were in dissolved condition. Except station-10, the other stations highlighted lower concentration of Cu, which was agreed with the findings of aforesaid authors.

The recommended maximum concentration of copper for drinking water supply with respect to USPH (E.C., 1980) and WHO (1992) standard were $1000 \mu\text{g.L}^{-1}$ and $2000 \mu\text{g.L}^{-1}$ respectively. The observed values were below the permissible level and the standard value of Cu industrial effluents of EQS for Bangladesh (1991) was 3ppm ($3000 \mu\text{g.L}^{-1}$). In the present findings the concentration level of Cu was much lower than the EQS value. So, the Cu concentrations found in the present investigation among all stations were not deleterious for the water body.

The concentration of Cu in five lakes of the Dhaka City ranged $<1.5 \mu\text{g.L}^{-1}$ to $9.52 \mu\text{g.L}^{-1}$ (Department of Chemistry, Jaganath University College, 1999). Rahman (1994) studied on the quantitative estimation of some trace metals (Foujdarhat-Kumira) in water were ranged as 0.092ppm and 0.033ppm ($92 \mu\text{g.L}^{-1}$ and $33 \mu\text{g.L}^{-1}$). The average value of Cu

was as 0.057 ± 0.019 ppm ($57 \pm 19 \mu\text{g.L}^{-1}$). The present investigation coincides with above authors.

The maximum concentration of Cd was recorded as $15.52 \mu\text{g.L}^{-1}$ at station-2 during the period of monsoon and the minimum was as $<2.08 \mu\text{g.L}^{-1}$ in rest of the stations.

The standard value of Cd for industrial effluents of (EQS, 1991) Bangladesh was 0.05 ppm ($50 \mu\text{g.L}^{-1}$). Recommended value of Cd from National Research Council, Canada (1995) for near shore seawater (Code No. CASS-3) was $0.030 \pm 0.005 \mu\text{g.ml}^{-1}$ ($30 \pm 5 \mu\text{g.L}^{-1}$) and for estuarine water (Code No. SLEW-2) was $0.019 \pm 0.002 \mu\text{g.ml}^{-1}$ ($19 \pm 2 \mu\text{g.L}^{-1}$). The concentrations found in the present investigation were lower than the EQS of Bangladesh and recommended value of National Research Council, Canada.

In the present investigation as most of the concentration were below the detection limit, the variation of Cd was minimum. Observation made by Khan and Rahman (1994) on the pollution of trace metals in the Karnafully River found minimum seasonal variation of Cd in the Sandip and Meghna estuary. Further Ouseph (1992) observed little seasonal variation in Cd concentration during his study on the dissolved and particulate trace metals in the Cochin estuary. So, the present findings are almost similar with Khan and Hossain (1996); Khan and Rahman (1994) and Ouseph (1992).

The concentration of cadmium showed in $< 2.00 \mu\text{g.L}^{-1}$ in all the five lakes of Dhaka City (Department of Chemistry, Jagannath University College, 1999). Heavy metals studied in Lake water Marjut, Egypt showed the regional average of Cd varied slightly from $0.49 \mu\text{g.L}^{-1}$ to $0.8 \mu\text{g.L}^{-1}$ (Massound *et. al.*, 1982). The concentration of cadmium in the Tropical lake Karaiba, Zimbabwe was $19 \mu\text{g.L}^{-1}$ (Hakan Barg *et. al.*, 1995). The present studies were quite lower than the permissible limit. In the present investigation, the concentration of cadmium was more or less similar with the findings of above authors.

The maximum concentration of Mn was recorded as $724\mu\text{g.L}^{-1}$ at station-10 (Production water of the Khulna Hardboard Mills) during the period of pre-monsoon and the lowest concentration was $7.25\mu\text{g.L}^{-1}$ at station-6 (Middle of the Bhairab River) during the same period. The recommended value of Mn from National Research Council, Canada (1995) for near seawater (CASS-3) was $2.51 \pm 0.36\mu\text{g.ml}^{-1}$ ($2510 \pm 360\mu\text{g.L}^{-1}$) and for estuarine water (Code No. SLEW-2) was $17.1 \pm 1.1\mu\text{g.ml}^{-1}$ ($17100 \pm 1100\mu\text{g.L}^{-1}$). The concentration of Mn found in the present investigation was much lower than the recommended value mentioned above and also than the EQS value of Bangladesh $5000\mu\text{g.L}^{-1}$. So the water quality was quite acceptable for living biota in respect of Mn concentration.

The maximum permissible USPH (E.C., 1980) and WHO (1992) standard of Manganese for drinking water purposes were $50\mu\text{g.L}^{-1}$ and $500\mu\text{g.L}^{-1}$ respectively. In the present investigation, the concentration level exceeded the recommended level. So pre-treatment may be recommended for drinking and irrigation purposes.

The maximum concentration of Pb was recorded as $70.7\mu\text{g.L}^{-1}$ at station-2 (Chemical drain water) during the period of monsoon which may occur due to incidental presence of suspended particles and the lowest concentration was $<5.47\mu\text{g.L}^{-1}$ at station-3 during the period of pre-monsoon. At most of this station the level of Pb were found to be less than the detection limit ($<5.47\mu\text{g.L}^{-1}$). The average concentration of Pb was always higher at station-10 than the other stations. These higher values were might be due to the presence of Pb content with the effluents discharged by the Khulna Hardboard Mills.

Dissolved Pb was studied by Abdullah (1974), Zigde *et. al.*, (1985), Satyanarayan *et.al.*, (1985) and Shen *et. al.*, (1989). They reported that the main cause of its input into the river water might be due to industrial, municipal or surface discharges, which is well agreement with the present investigation. The recommended value of Pb from National Research Council, Canada (1995) for estuarine water (Code No. SLEW-2) was $0.027 \pm 0.005 \mu\text{g.ml}^{-1}$ ($27 \pm 5\mu\text{g.L}^{-1}$). The level of Pb found in the present investigation was

lower than the recommended values of National Research Council, Canada except station-2 during the period of monsoon which may be due to incidental presence of particular source.

The recommended value of drinking water WHO (1992) was $10\mu\text{g.L}^{-1}$. The present investigation (station-8, 9, 10, 11 and 12) exceeded the recommended value. This might be due to agriculture activities, shipping activities or industrial effluents. Water in these investigated areas were harmful for drinking purpose.

The standard value of Pb for industrial effluents of EQS for Bangladesh (1991) was 0.1ppm ($100\mu\text{g.L}^{-1}$). In the present study, except the highest value was as $70.7\mu\text{g.L}^{-1}$ at station-2 during period of monsoon the level of Pb through out the year was lower at all stations. So It may be concluded that the concentrations of Pb in the present investigation is well agreement with the EQS value.

The maximum concentration of chromium was again recorded as $61.3\mu\text{g.L}^{-1}$ at station-2 during the monsoon period and the lowest concentration was observed $<14.7\mu\text{g.L}^{-1}$ rest of the other stations during the all periods. The highest concentration observed in the station-2 (Chemical drain water) of KNM than the other stations.

The concentration of chromium below $<14.7\mu\text{g.L}^{-1}$ was found in all stations except station-2 (Chemical drain water). The permissible limit (EQS) of chromium in drinking was $50\mu\text{g.L}^{-1}$ (E. C., 1980). So except in station-2 it was not harmful for aquatic biota as well as for human consumption.

Recommended values of Cr from national Research Council, Canada (1995) for near shore seawater (Code No. ASS-3) was $0.092 \pm 0.006\mu\text{g.ml}^{-1}$ ($92 \pm 6\mu\text{g.L}^{-1}$) and for estuarine water (Code No. SLEW-2) was $0.169 \pm 0.018\mu\text{g.ml}^{-1}$ ($169 \pm 18\mu\text{g.L}^{-1}$). Khan and Hossain (1996) recorded higher concentration of Cr found in the present investigation was within the safe limit mentioned above and was also much lower than

the EQS value 0.05ppm ($50\mu\text{g.L}^{-1}$) of Bangladesh except in station-2 which was exceeded EQS value. So in this station-2 the water in chemical drain needs pretreatment before discharge.

In the present investigation, the variations of Cr concentrations were minimum. Khan and Hossain (1996) and Khan and Nath (1996) also reported minimum seasonal variation of Cr for the Bangladesh coast from Karnafully River to the Meghna estuary. So the present finding well correlates with their observations.

The maximum $42.18\mu\text{g.L}^{-1}$ concentration of Co at station-2 (chemical drain water) during the monsoon period and lower value ($<2.11\mu\text{g.L}^{-1}$) was observed in all other station during the period of monsoon and post-monsoon.

USPH guideline for cobalt for drinking water was $1000\mu\text{g.L}^{-1}$ (E.C.,1980). Cobalt concentration of the Dhaka city ranged from <1.41 to $7.1\mu\text{g.L}^{-1}$ (Department of Chemistry, Jagannath University College, 1999). The present findings are in well agreement with the above standard certified limits as mentioned.

The maximum concentration of nickel was recorded as $64.74\mu\text{g.L}^{-1}$ at station-2 (chemical drain water) of the KNM during the period of monsoon and the minimum concentration of nickel was as $<2.46\mu\text{g.L}^{-1}$ at station-3 during the all periods, station-4 during the monsoon period, station-6 during the pre-monsoon, station-8 & 12 during the pre-monsoon period.

The recommended values of Ni from National Research Council, Canada (1995) for near shore seawater (Code No. CASS-3) was $0.386 \pm 0.062 \mu\text{g.ml}^{-1}$ ($386 \pm 62 \mu\text{g.L}^{-1}$) and for estuarine water (Code No. SLEW-2) was $0.709 \pm 0.054 \mu\text{g.ml}^{-1}$ ($709 \pm 54\mu\text{g.L}^{-1}$). The concentration of Ni found in the present investigation was very low than the recommended values.

In the present investigation the little seasonal fluctuation observed in Ni concentration. However, it was within the permissible limit. Khan and Nath (1996) observed considerable variation of Ni Concentration. Another study by Khan and Hossain (1996) also reported high seasonal variation of Ni in the Karnafully estuary. USPH standard was $1000 \mu\text{g.L}^{-1}$ (E.C.,1980). Our experimental value was lower than that permissible limit. So the quality of water in the studied area was not harmful as far as the Ni concentration was concerned.

5.5. CONCLUSION

The objective of this research program was to study the level of trace metals in the effluents from Khulna Newsprint and Hardboard Mills and Bhairab river water. From the results of the above investigation, we can draw the conclusion, whether there is any pollution effect in river water due to the discharge from these industries. In most of the stations the level of Fe, Cu, Pb, Cd, Mn, Cr, Co and Ni were found to be within the normal range. In some cases, the concentration level of Fe, Mn, Cd, Cr were slightly higher than the permissible level.

Iron concentration at station-4 (Discharge are of KNM) was exceeded the EQS (1991) value during the period of pre-monsoon. The level of Mn at station-10 (Production water of KHM) during the period of pre-monsoon was exceeded the recommended level. Pulp is also abundant in the production water at the station-10, which might be harmful for the use of this water for domestic, fisheries, irrigation and other purposes. So, a minor pre-treatment is required before using this matter for domestic, fisheries, irrigation and other purposes. It can be stated that the Mn level in ground water in Khulna zone is also higher in some areas.

From the overall study it might be observed that in cause of station-2 (Chemical drain water) of KNM the level of Cd, Pb, Cr, Co and Ni is much higher in monsoon season than the level of these elements in other stations. Even the concentration level of these elements in the station-2 is much lower in other seasons. These high values may be due to the fact that in the time of sampling, there might be incidental presence of particulate matters containing high elemental level or some chemicals were being used for production in the KNM. In future a throw out study can be under taken particularly in this location through out the year. If it is not found to be a incidental case, the discharge from Chemical drain water should have a pretreatment before discharge.

CHAPTER SIX

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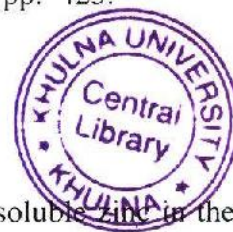
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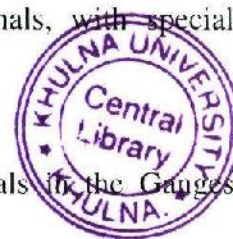
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TABLES

Table: 3. Seasonal variation of trace metal concentrations at station-1 (effluent from grinding water in Khulna Newsprint Mills)

Atomic No.	Trace Metals	Wave Length(nm)	Silt (nm)	Season	Concentration $\mu\text{g.L}^{-1}$
26	Fe	248.3	0.2	Pre-monsoon	312
				Monsoon	93.2
				Post-monsoon	134
29	Cu	324.8	0.7	Pre-monsoon	5.50
				Monsoon	5.20
				Post-monsoon	7.50
48	Cd	228.8	0.7	Pre-monsoon	<2.08
				Monsoon	<2.08
				Post-monsoon	<2.08
25	Mn	279.5	0.2	Pre-monsoon	62.0
				Monsoon	33.75
				Post-monsoon	49.25
82	Pb	283.3	0.7	Pre-monsoon	8.21
				Monsoon	6.66
				Post-monsoon	6.84
24	Cr	357.9	0.7	Pre-monsoon	<14.7
				Monsoon	<14.7
				Post-monsoon	<14.7
27	Co	240.7	0.2	Pre-monsoon	2.11
				Monsoon	<2.11
				Post-monsoon	<2.11
28	Ni	232	0.2	Pre-monsoon	11.06
				Monsoon	4.73
				Post-monsoon	7.37

Table: 4 Seasonal variation of trace metal concentrations at station-2 (effluent from chemical drain water in KNM)

Atomic No.	Trace Metals	Wave Length(nm)	Silt (nm)	Season	Concentration $\mu\text{g.L}^{-1}$
26	Fe	248.3	0.2	Pre-monsoon	2341
				Monsoon	62.52
				Post-monsoon	1976
29	Cu	324.8	0.7	Pre-monsoon	2.50
				Monsoon	11.2
				Post-monsoon	2.0
48	Cd	228.8	0.7	Pre-monsoon	<2.08
				Monsoon	15.52
				Post-monsoon	<2.08
25	Mn	279.5	0.2	Pre-monsoon	144
				Monsoon	34.25
				Post-monsoon	93.75
82	Pb	283.3	0.7	Pre-monsoon	8.21
				Monsoon	70.7
				Post-monsoon	9.58
24	Cr	357.9	0.7	Pre-monsoon	14.7
				Monsoon	61.3
				Post-monsoon	<14.7
27	Co	240.7	0.2	Pre-monsoon	4.22
				Monsoon	42.18
				Post-monsoon	4.57
28	Ni	232	0.2	Pre-monsoon	6.14
				Monsoon	64.74
				Post-monsoon	5.32

Table: 5 Seasonal variation of trace metal concentrations at station-3 (discharge surface water from KNM)

Atomic No.	Trace Metals	Wave Length(nm)	Silt (nm)	Season	Concentration $\mu\text{g.L}^{-1}$
26	Fe	248.3	0.2	Pre-monsoon	2175
				Monsoon	133
				Post-monsoon	392
29	Cu	324.8	0.7	Pre-monsoon	3.50
				Monsoon	5.46
				Post-monsoon	4.50
48	Cd	228.8	0.7	Pre-monsoon	<2.08
				Monsoon	<2.08
				Post-monsoon	<2.08
25	Mn	279.5	0.2	Pre-monsoon	93.0
				Monsoon	34.37
				Post-monsoon	52.25
82	Pb	283.3	0.7	Pre-monsoon	<5.47
				Monsoon	5.47
				Post-monsoon	6.84
24	Cr	357.9	0.7	Pre-monsoon	<14.7
				Monsoon	<14.7
				Post-monsoon	<14.7
27	Co	240.7	0.2	Pre-monsoon	5.28
				Monsoon	-
				Post-monsoon	4.22
28	Ni	232	0.2	Pre-monsoon	<2.46
				Monsoon	<2.46
				Post-monsoon	<2.46

Table: 6 Seasonal variation of trace metal concentrations at station-4 (another discharge surface water from KNM).

Atomic No.	Trace Metals	Wave Length(nm)	Silt (nm)	Season	Concentration $\mu\text{g.L}^{-1}$
26	Fe	248.3	0.2	Pre-monsoon	2756
				Monsoon	342
				Post-monsoon	2497
29	Cu	324.8	0.7	Pre-monsoon	5.50
				Monsoon	7.03
				Post-monsoon	6.50
48	Cd	228.8	0.7	Pre-monsoon	<2.08
				Monsoon	<2.08
				Post-monsoon	<2.08
25	Mn	279.5	0.2	Pre-monsoon	168
				Monsoon	42.37
				Post-monsoon	119
82	Pb	283.3	0.7	Pre-monsoon	6.84
				Monsoon	8.21
				Post-monsoon	8.21
24	Cr	357.9	0.7	Pre-monsoon	14.7
				Monsoon	<14.7
				Post-monsoon	<14.7
27	Co	240.7	0.2	Pre-monsoon	<2.11
				Monsoon	<2.11
				Post-monsoon	<2.11
28	Ni	232	0.2	Pre-monsoon	5.73
				Monsoon	<2.46
				Post-monsoon	4.91

Table: 7 Seasonal variation of trace metal concentrations at station-5 (discharge surface machine water from KNM)

Atomic No.	Trace Metals	Wave Length(nm)	Silt (nm)	Season	Concentration $\mu\text{g.L}^{-1}$
26	Fe	248.3	0.2	Pre-monsoon	1693
				Monsoon	187
				Post-monsoon	206
29	Cu	324.8	0.7	Pre-monsoon	16.0
				Monsoon	6.51
				Post-monsoon	12.5
48	Cd	228.8	0.7	Pre-monsoon	<2.08
				Monsoon	<2.08
				Post-monsoon	<2.08
25	Mn	279.5	0.2	Pre-monsoon	89.5
				Monsoon	48.0
				Post-monsoon	63.75
82	Pb	283.3	0.7	Pre-monsoon	<5.47
				Monsoon	<5.47
				Post-monsoon	5.47
24	Cr	357.9	0.7	Pre-monsoon	<14.7
				Monsoon	<14.7
				Post-monsoon	<14.7
27	Co	240.7	0.2	Pre-monsoon	3.52
				Monsoon	<2.11
				Post-monsoon	2.11
28	Ni	232	0.2	Pre-monsoon	5.73
				Monsoon	4.73
				Post-monsoon	6.14

Table: 8 Seasonal variation of trace metal concentrations at station-6 (middle of Bhairab river water from KNM)

Atomic No.	Trace Metals	Wave Length(nm)	Silt (nm)	Season	Concentration $\mu\text{g.L}^{-1}$
26	Fe	248.3	0.2	Pre-monsoon	638
				Monsoon	359
				Post-monsoon	770
29	Cu	324.8	0.7	Pre-monsoon	5.50
				Monsoon	4.94
				Post-monsoon	6.0
48	Cd	228.8	0.7	Pre-monsoon	<2.08
				Monsoon	<2.08
				Post-monsoon	<2.08
25	Mn	279.5	0.2	Pre-monsoon	7.25
				Monsoon	36.12
				Post-monsoon	9.75
82	Pb	283.3	0.7	Pre-monsoon	<5.47
				Monsoon	5.47
				Post-monsoon	5.47
24	Cr	357.9	0.7	Pre-monsoon	<14.7
				Monsoon	<14.7
				Post-monsoon	<14.7
27	Co	240.7	0.2	Pre-monsoon	<2.11
				Monsoon	2.5
				Post-monsoon	2.11
28	Ni	232	0.2	Pre-monsoon	<2.46
				Monsoon	6.31
				Post-monsoon	4.91

Table: 9 Seasonal variation of trace metal concentrations at station-7 (100 meters down of the Bhairab river surface water from KNM)

Atomic No.	Trace Metals	Wave Length(nm)	Silt (nm)	Season	Concentration $\mu\text{g.L}^{-1}$
26	Fe	248.3	0.2	Pre-monsoon	823
				Monsoon	664
				Post-monsoon	936
29	Cu	324.8	0.7	Pre-monsoon	8.0
				Monsoon	6.51
				Post-monsoon	8.25
48	Cd	228.8	0.7	Pre-monsoon	<2.08
				Monsoon	<2.08
				Post-monsoon	<2.08
25	Mn	279.5	0.2	Pre-monsoon	10.5
				Monsoon	35.5
				Post-monsoon	23.0
82	Pb	283.3	0.7	Pre-monsoon	<5.47
				Monsoon	6.66
				Post-monsoon	5.47
24	Cr	357.9	0.7	Pre-monsoon	<14.7
				Monsoon	<14.7
				Post-monsoon	<14.7
27	Co	240.7	0.2	Pre-monsoon	4.22
				Monsoon	<2.11
				Post-monsoon	4.57
28	Ni	232	0.2	Pre-monsoon	6.55
				Monsoon	4.73
				Post-monsoon	7.37

Table:10 Seasonal variation of trace metal concentrations at station-8 (200 meters down of the Bhairab river surface water from KNM).

Atomic No.	Trace Metals	Wave Length(nm)	Silt (nm)	Season	Concentration $\mu\text{g.L}^{-1}$
26	Fe	248.3	0.2	Pre-monsoon	1428
				Monsoon	773
				Post-monsoon	1235
29	Cu	324.8	0.7	Pre-monsoon	17.5
				Monsoon	5.98
				Post-monsoon	12.5
48	Cd	228.8	0.7	Pre-monsoon	<2.08
				Monsoon	<2.08
				Post-monsoon	<2.08
25	Mn	279.5	0.2	Pre-monsoon	280
				Monsoon	41.62
				Post-monsoon	188
82	Pb	283.3	0.7	Pre-monsoon	10.95
				Monsoon	5.47
				Post-monsoon	8.21
24	Cr	357.9	0.7	Pre-monsoon	<14.7
				Monsoon	<14.7
				Post-monsoon	<14.7
27	Co	240.7	0.2	Pre-monsoon	2.81
				Monsoon	<2.11
				Post-monsoon	2.11
28	Ni	232	0.2	Pre-monsoon	<2.46
				Monsoon	6.31
				Post-monsoon	4.91

Table: 11 Seasonal variation of trace metal concentrations at station-9 (300 meters down of the Bhairab river from KNM, near Navy Port).

Atomic No.	Trace Metals	Wave Length(nm)	Silt (nm)	Season	Concentration $\mu\text{g.L}^{-1}$
26	Fe	248.3	0.2	Pre-monsoon	1859
				Monsoon	964
				Post-monsoon	1368
29	Cu	324.8	0.7	Pre-monsoon	14.0
				Monsoon	7.29
				Post-monsoon	11.0
48	Cd	228.8	0.7	Pre-monsoon	<2.08
				Monsoon	<2.08
				Post-monsoon	<2.08
25	Mn	279.5	0.2	Pre-monsoon	237
				Monsoon	55.25
				Post-monsoon	194
82	Pb	283.3	0.7	Pre-monsoon	10.95
				Monsoon	6.66
				Post-monsoon	8.21
24	Cr	357.9	0.7	Pre-monsoon	<14.7
				Monsoon	<14.7
				Post-monsoon	<14.7
27	Co	240.7	0.2	Pre-monsoon	2.11
				Monsoon	<2.11
				Post-monsoon	2.81
28	Ni	232	0.2	Pre-monsoon	2.46
				Monsoon	6.31
				Post-monsoon	7.37

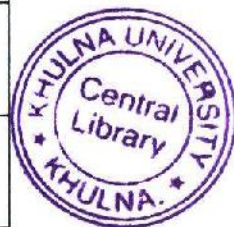


Table: 12 Seasonal variation of trace metal concentrations at station-10 (production water from Khulna Hardboard Mills).

Atomic No.	Trace Metals	Wave Length(nm)	Silt (nm)	Season	Concentration $\mu\text{g.L}^{-1}$
26	Fe	248.3	0.2	Pre-monsoon	1727
				Monsoon	1186
				Post-monsoon	1501
29	Cu	324.8	0.7	Pre-monsoon	8.0
				Monsoon	66.14
				Post-monsoon	9.0
48	Cd	228.8	0.7	Pre-monsoon	<2.08
				Monsoon	<2.08
				Post-monsoon	<2.08
25	Mn	279.5	0.2	Pre-monsoon	724
				Monsoon	385
				Post-monsoon	525
82	Pb	283.3	0.7	Pre-monsoon	19.16
				Monsoon	13.33
				Post-monsoon	20.53
24	Cr	357.9	0.7	Pre-monsoon	-
				Monsoon	<14.7
				Post-monsoon	<14.7
27	Co	240.7	0.2	Pre-monsoon	2.11
				Monsoon	2.5
				Post-monsoon	2.46
28	Ni	232	0.2	Pre-monsoon	-
				Monsoon	12.63
				Post-monsoon	9.01

Table: 13 Seasonal variation of trace metal concentrations at station-11 (discharge water from Khulna Hardboard Mills).

Atomic No.	Trace Metals	Wave Length(nm)	Silt (nm)	Season	Concentration $\mu\text{g.L}^{-1}$
26	Fe	248.3	0.2	Pre-monsoon	1295
				Monsoon	1351
				Post-monsoon	1215
29	Cu	324.8	0.7	Pre-monsoon	12.0
				Monsoon	22.39
				Post-monsoon	15.0
48	Cd	228.8	0.7	Pre-monsoon	<2.08
				Monsoon	<2.08
				Post-monsoon	<2.08
25	Mn	279.5	0.2	Pre-monsoon	135
				Monsoon	189
				Post-monsoon	119
82	Pb	283.3	0.7	Pre-monsoon	8.21
				Monsoon	13.33
				Post-monsoon	12.0
24	Cr	357.9	0.7	Pre-monsoon	<14.7
				Monsoon	<14.7
				Post-monsoon	<14.7
27	Co	240.7	0.2	Pre-monsoon	2.81
				Monsoon	2.5
				Post-monsoon	3.52
28	Ni	232	0.2	Pre-monsoon	2.46
				Monsoon	15
				Post-monsoon	3.27

Table: 14 Seasonal variation of trace metal concentrations at station-12 (discharge surface water from Khulna Hardboard Mills into the Bhairab river).

Atomic No.	Trace Metals	Wave Length(nm)	Silt (nm)	Season	Concentration $\mu\text{g.L}^{-1}$
26	Fe	248.3	0.2	Pre-monsoon	996
				Monsoon	873
				Post-monsoon	936
29	Cu	324.8	0.7	Pre-monsoon	10.0
				Monsoon	14.84
				Post-monsoon	17.75
48	Cd	228.8	0.7	Pre-monsoon	<2.08
				Monsoon	<2.08
				Post-monsoon	<2.08
25	Mn	279.5	0.2	Pre-monsoon	62.5
				Monsoon	65.5
				Post-monsoon	75.0
82	Pb	283.3	0.7	Pre-monsoon	5.47
				Monsoon	8.20
				Post-monsoon	10.95
24	Cr	357.9	0.7	Pre-monsoon	<14.7
				Monsoon	<14.7
				Post-monsoon	<14.7
27	Co	240.7	0.2	Pre-monsoon	<2.11
				Monsoon	<2.11
				Post-monsoon	<2.11
28	Ni	232	0.2	Pre-monsoon	<2.46
				Monsoon	3.15
				Post-monsoon	4.09

Table: 15 Seasonal variation of trace metal concentrations at station-13 (surface water from Basundia, Jessore).

Atomic No.	Trace Metals	Wave Length(nm)	Silt (nm)	Season	Concentration $\mu\text{g.L}^{-1}$
26	Fe	248.3	0.2	Pre-monsoon	325
				Monsoon	67.8
				Post-monsoon	372
29	Cu	324.8	0.7	Pre-monsoon	5.00
				Monsoon	3.64
				Post-monsoon	5.50
48	Cd	228.8	0.7	Pre-monsoon	<2.08
				Monsoon	<2.08
				Post-monsoon	<2.08
25	Mn	279.5	0.2	Pre-monsoon	10.5
				Monsoon	9.50
				Post-monsoon	11.0
82	Pb	283.3	0.7	Pre-monsoon	<5.47
				Monsoon	<5.47
				Post-monsoon	5.47
24	Cr	357.9	0.7	Pre-monsoon	<14.7
				Monsoon	<14.7
				Post-monsoon	<14.7
27	Co	240.7	0.2	Pre-monsoon	<2.11
				Monsoon	<2.11
				Post-monsoon	<2.11
28	Ni	232	0.2	Pre-monsoon	5.73
				Monsoon	3.94
				Post-monsoon	6.55

Table 16 Standard concentration calibration for trace metals.

Cr	Absorbance	0.01	0.019	0.032
	Concentration (ppm)	0.5	1	2
Mn	Absorbance	0.101	0.201	0.347
	Concentration (ppm)	0.5	1	2
Fe	Absorbance	0.037	0.075	0.152
	Concentration (ppm)	0.5	1	2
Cu	Absorbance	0.05	0.101	0.198
	Concentration (ppm)	0.5	1	2
Cd	Absorbance	0.119	0.228	0.438
	Concentration (ppm)	0.5	1	2
Pb	Absorbance	0.009	0.0185	0.037
	Concentration (ppm)	0.5	1	2
Co	Absorbance	0.037	0.071	0.14
	Concentration (ppm)	0.5	1	2
Ni	Absorbance	0.034	0.061	0.12
	Concentration (ppm)	0.5	1	2

Table 17 USPHS (United States Public Health Drinking Water) water quality criteria for domestic water supplies.

Parameters	USPH standard
Chloride	250 mg/L
Total Dissolved Solids	500 mg/L
Suspended Solids	5.00 mg/L
pH	6-8.5
Alkalinity (CaCO ₃ units)	30-500µg/l
Lead	50µg/l
Cadmium	10µg/l
Iron (Filterable)	<300µg/l
Zinc	5000µg/l
Copper	1000µg/l
Chromium	50µg/l
Manganese	50µg/l
Cobalt	1000µg/l
Nickel	1000µg/l

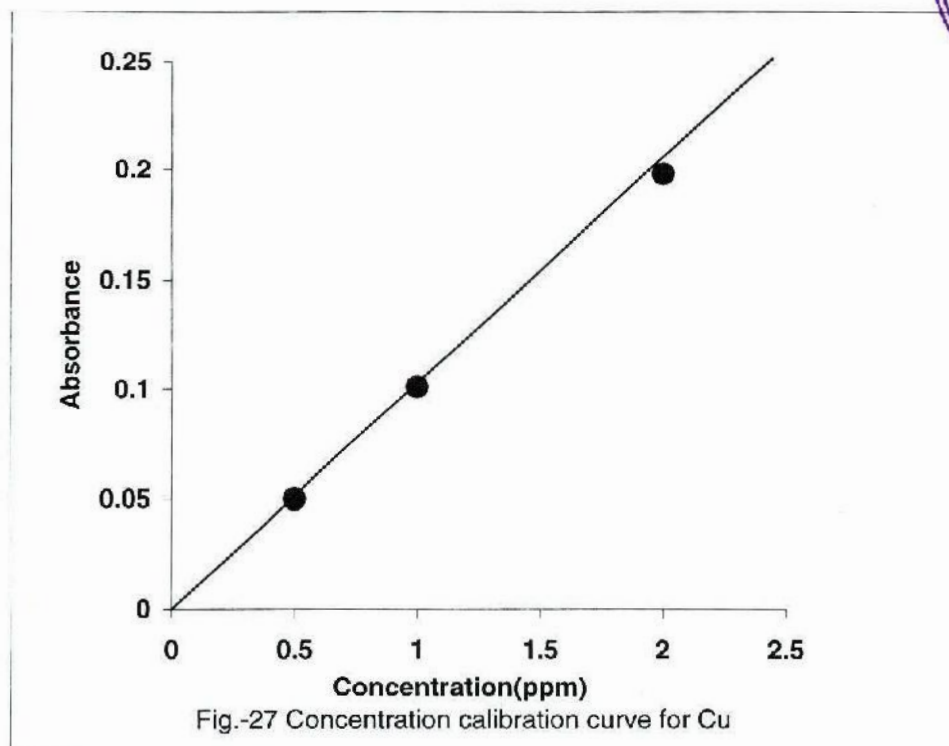
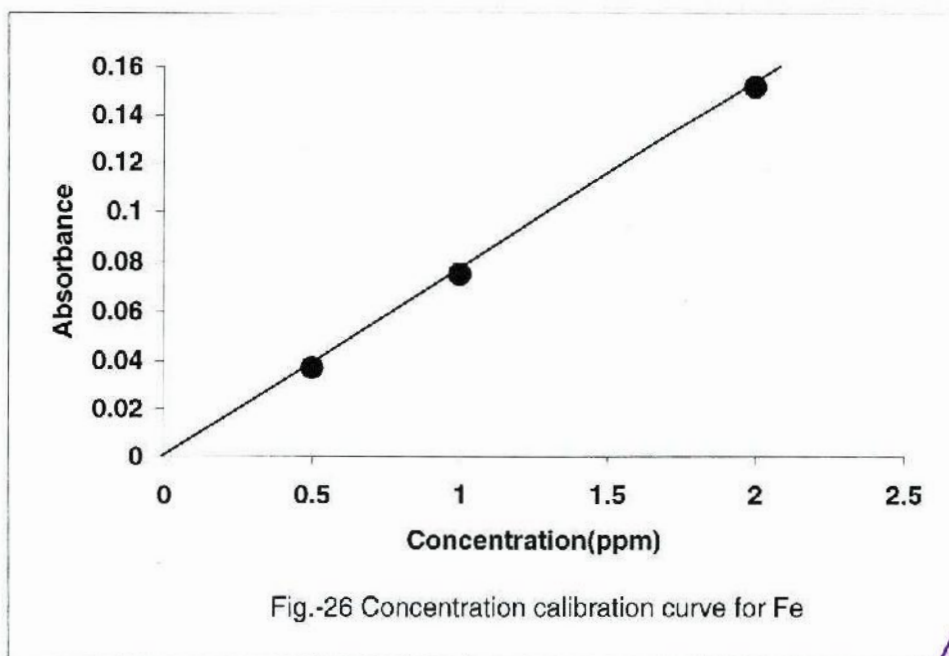
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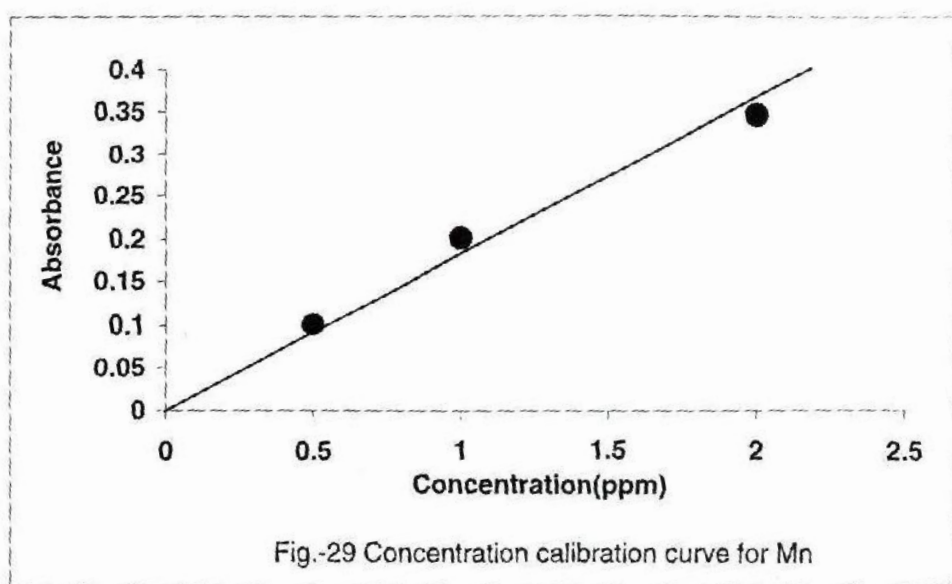
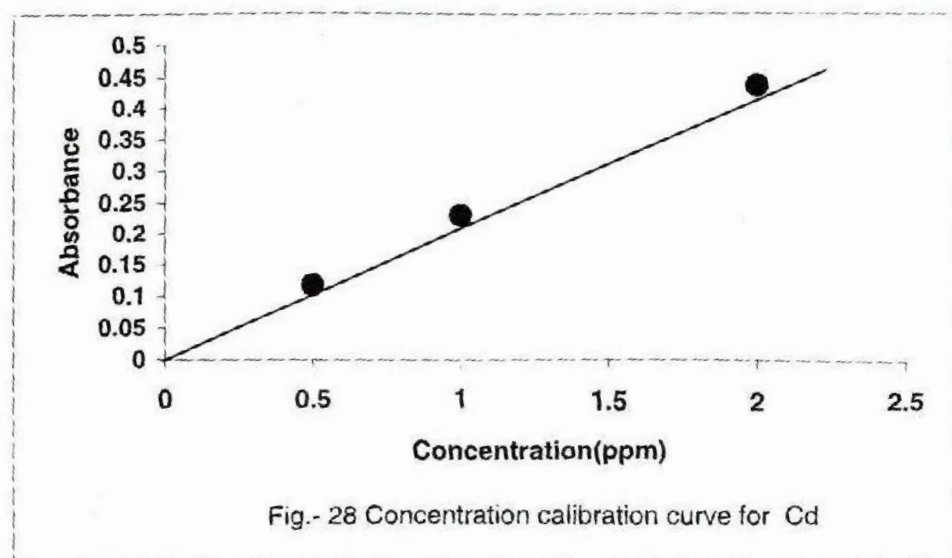
Table 18 World Health Organization (WHO) Guidelines for Drinking Water Quality.

Parameter	Guide line value
Pb (Lead)	0.01 mg/L
Cd(Cadmium)	0.003 mg/L
Fe(Iron)	0.3 mg/L
Cr (Chromium)	0.05 mg/L
Cu(Copper)	2.00mg/L(P)
Mn (Manganese)	0.5mg/L
Nickel	0.02 mg/L
Chloride	250 mg/L
Suspended Solids	1000 mg/L

Source: WHO, 1992.

FIGURES





Concentration calibration curve for Cr

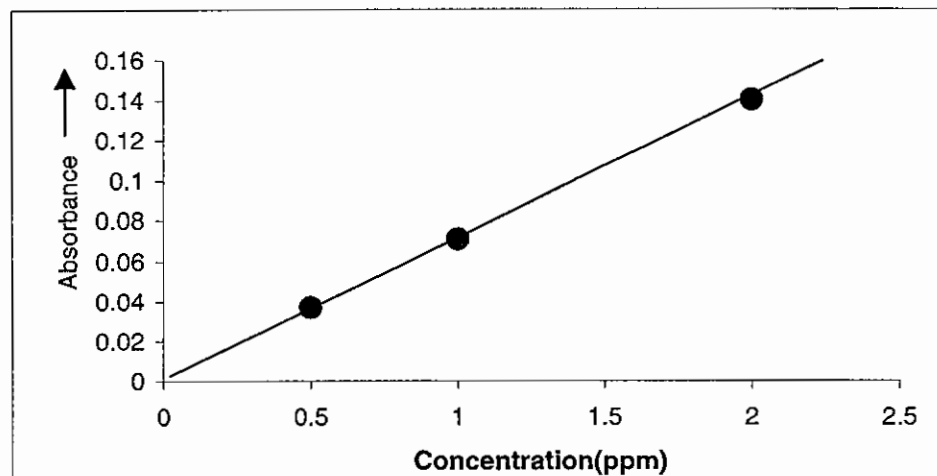


Fig.-32 Concentration calibration curve for Co

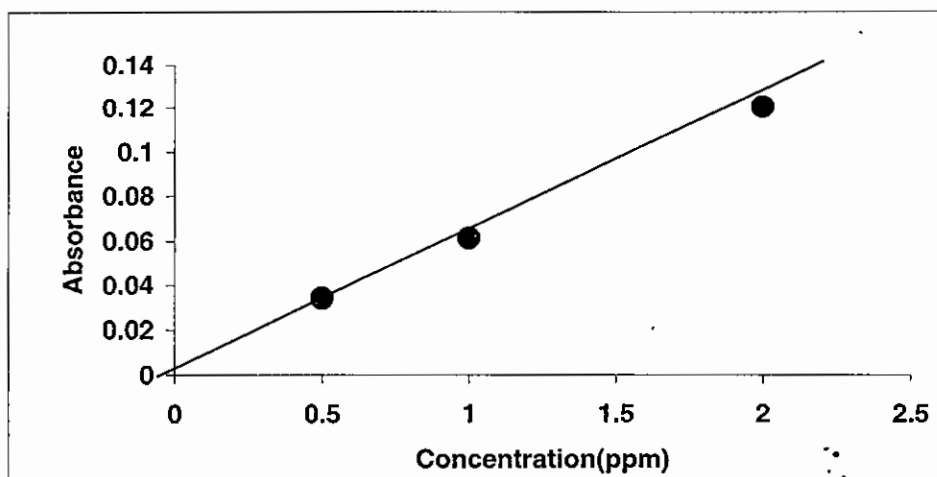


Fig.- 33 Concentration calibration curve for Ni

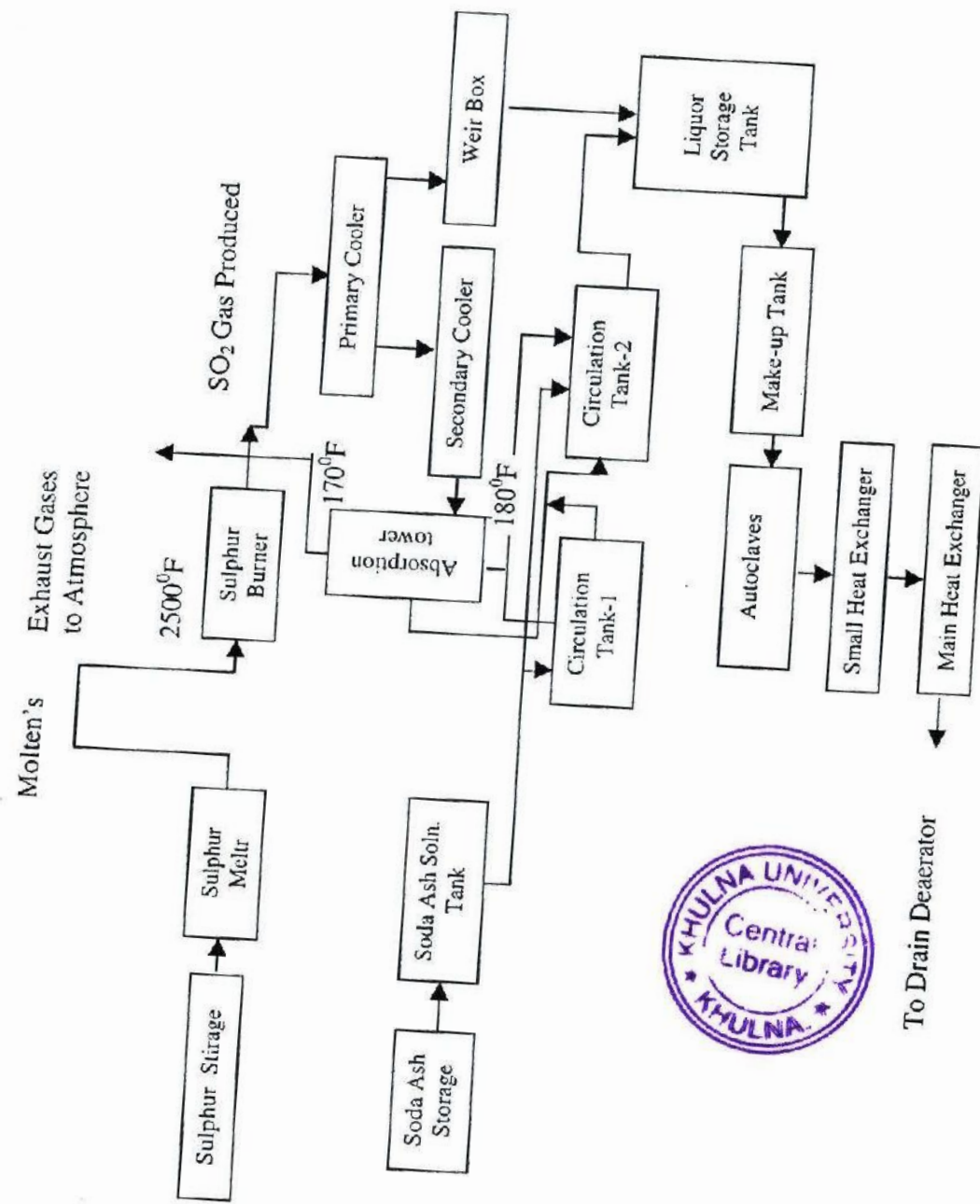


Fig.-34 Flow sheet product of cooking liquor of the KNM

