

Study on the seasonal variations of trace elements in *Garra lamta* (Hamilton) from selected rivers of West Khasi Hills, Meghalaya

Abstract

***Precious Stone Longwai
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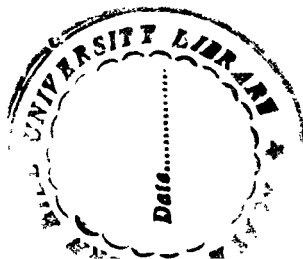
***Thesis submitted
In Fulfillment of the Requirement of the Degree of Doctor of
Philosophy in Zoology***

***North Eastern Hill University
Shillong – 793 022, India***

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In this study, we try to monitor the levels of trace elements (Fe, Zn, Mn, Cu, Ni and Co) in whole body of *Garra lamta* (Hamilton) keeping in view scarcity of data on this fishes. This study was designed to establish the distributions and seasonal variations of trace metals (Fe, Zn, Mn, Cu, Ni and Co), in commonly available fish species of the area and also to study the seasonal variation of trace elements and some of the important abiotic parameters like alkalinity, dissolve oxygen, pH and temperature. Correlation studies of trace elements between the two aquatic ecosystems are also studied. The objective of the baseline study of an ecological assessment is to provide adequate and accurate ecological baseline information. It is found out that all the selected elements falls well below the permissible value of World Health Organization, and the area can be regarded as pristine areas and it will not pose any threats to the biotic communities in the region.

Concentration of trace elements in the tissue of fish sample provide a time-integrated assessment of contaminant and a better understanding of the complexities of the distribution and effects of various trace elements. Trace elements can be ingested with stream bed sediment in the water column by benthic organisms and can accumulate and move through the food chain. Fishes are particularly good indicators of biologically available contaminant, because environmental contaminants can accumulates in their bodies at higher concentrations than in surrounding waters. Many trace elements concentrate in the viscera of fish such as liver and kidneys. The concentration of trace elements may vary depending on the number of factors such as the chemical properties of the elements and the fish species.

The uptake and accumulation of trace elements by organisms depends on many factors including physical and chemical form of the elements in the environment, the biological needs for specific elements or its homologue by the animal, seasons and other climatic factors such as temperature, the age of organisms, the specific tissues involved and the specific characteristic of the local ecosystem. Biological uptake is associated with metabolism which is dependent as well as function of body size, age, sex, physical conditions, metabolic rate and deposition of stable element where accumulation occurs. Hence to understand the bio accumulation and distribution of selected trace elements in this species the study was conducted under natural conditions.

In the present study it is found that over a period of two years Fe concentrations in whole body of *Garra lamta* from Kynshi River shows minimum concentrations of 29.40 $\mu\text{g/g}$ during the season of autumn in the year 2005, and maximum concentration of 95.50 $\mu\text{g/g}$ during summer season of the year 2005. Zn concentrations have minimum concentrations of 31.40 $\mu\text{g/g}$ during the season of autumn in the year 2004, and maximum concentration of 95.40 $\mu\text{g/g}$ during summer season of the year 2005. Mn concentrations have minimum concentrations of 2.37 $\mu\text{g/g}$ during the season of winter in the year 2004, and maximum concentration of 10.33 $\mu\text{g/g}$ during summer season of the year 2004. Ni concentrations have minimum concentrations of 0.20 $\mu\text{g/g}$ during the season of spring in the year 2004, and maximum concentration of 3.18 $\mu\text{g/g}$ during summer season of the year 2004. Co concentrations have minimum concentrations of 0.76 $\mu\text{g/g}$ during the season of winter in the year 2005, and maximum concentration of

1.54 $\mu\text{g/g}$ during summer season of the year 2004. Bio-accumulation factor of all the selected elements shows significant variation throughout the period of study.

In the study of trace elemental concentration in water samples of Kynshi River it is found that over a period of two years, Fe concentrations have minimum concentrations of 16.20 $\mu\text{g/l}$ during winter season in the year 2004, and maximum concentration of 75.34 $\mu\text{g/l}$ during summer season of the year 2004. Zn concentrations have minimum concentrations of 3.77 $\mu\text{g/l}$ during spring season in the year 2004, and maximum concentration of 17.86 $\mu\text{g/l}$ during summer season of the year. Mn concentrations have minimum concentrations of 12.57 $\mu\text{g/l}$ during spring season in the year 2004, and maximum concentration of 25.52 $\mu\text{g/l}$ during summer season of the year 2005. Cu concentrations have minimum concentrations of 0.39 $\mu\text{g/l}$ during winter season in the year 2005, and maximum concentration of 2.45 $\mu\text{g/l}$ during summer season of the year 2005. Ni concentrations have minimum concentrations of 2.73 $\mu\text{g/l}$ during winter season in the year 2005, and maximum concentration of 27.55 $\mu\text{g/l}$ during summer season of the year 2004. Co concentrations have minimum concentrations of 6.48 $\mu\text{g/l}$ during winter season in the year 2004, and maximum concentration of 13.58 $\mu\text{g/l}$ during summer season of the year 2004. It is found that the concentrations of all the selected elements were within the acceptable standards of WHO, and therefore at this concentration the elements will not pose any serious threat to the life of biota or man as a consumer.

Total alkalinity ranges from 16.50 to 24.00 mg/l in the sampled aquatic ecosystems. Alkalinity is, however, primarily attributed presently to methyl orange

alkalinity, which in turn is attributed to bicarbonate ions. The stated salient feature represented a characteristic attribute of acidic-circum neutral waters and also corresponded with identical results from several biotopes of N. E. India. Dissolved Oxygen of water bodies in the study areas and extent of pH variations confirmed with observations in various aquatic biotopes of the state of Meghalaya and elsewhere in Northeastern India. The variations in water temperature affirm “subtropical nature” of the sampled habitats and, in turn, also concur with the results of from subtropical environs of N. E. India.

Studies on the fecundity of *Garra lamta* from Kynshi and Rilang River in the year 2004 and 2005 it is found that at different length ranges, fish shows different fecundity, and significant highest mean fecundity was found during monsoon period. Fecundity plays a significant role to evaluate the commercial potentialities of fish stock and also be used to assess the abundance and reproductive potential of the spawning stock. At present the knowledge of fecundity has been applied for detecting the different populations of the same species of fish in different location. In this study, GSI clearly shows that *Garra lamta* has a wide spawning season (March-November) in fresh water environments of West Khasi Hills Districts of Meghalaya. This study was aimed to provide information regarding the natural background concentration of selected elements and their accumulation factor in selected fish species. Seasonal variation of all the elements and important abiotic parameters are also taken into consideration from both the study sites during the period of study. Correlation studies of trace elements between the two aquatic ecosystems also taken into consideration.

Contamination of fresh water environment by metals has risen in recent years due to the global population increase and industrial development. The distribution of heavy metals in the different components of fresh water ecosystem is regulated by physico-chemical processes, e.g. dilution, diffusion, precipitation and sorption, as well as other processes involving aquatic organisms, such as uptake and elimination. Biota is recognized as an important indicator of heavy-metal contamination of the marine environment. Fishes are used as indicators of marine pollution because they are relatively large and easily identified. Baseline surveys of the concentration of heavy metals in selected fish species have been conducted on several coasts around the world. The objective of the present study was to evaluate the background concentration and seasonal variation of selected elements in whole body of *Garra lamta* and also the seasonal variation of the selected elements from the water bodies of the two rivers. This species were selected because it has different habitats and feeding habits, and could be representative of different sources of heavy metals and also the most common fishes of the area which is consumed by the local populace.

Metals are natural constituents of the environment. At high concentrations, trace metals can become toxic for living organisms and behave as conservative pollutants. Metals enter the environment mainly by two means: (i) natural processes (for example, erosion of rocks, volcanic activity, forest fires) and (ii) processes due to human activities. Some anthropogenic activities may add considerable amounts of polluting compounds, which will influence the existing natural aquatic system. Metals are frequently released in large quantities during different processes derived from human activities and may lead to

major destruction of aquatic ecosystems. Moreover, human beings located at places contaminated by heavy metals could be especially sensitive to these contaminants due to bioaccumulation. At low concentrations, an element plays an important role in metabolic and fermentation processes, as an enzyme activator, stabilizer and functional component of proteins. It has been stated that for all trace elements that considered to be essential, including iron, there exists a fairly narrow “concentration window” between the essential and toxic levels. Iron is a moderately toxic element when compared with other transition metals. For the determination of trace metals in natural and mineral waters different Spectrochemical methods are used. However, flame atomic absorption spectrometry (FAAS) is one of the most extensively used techniques for determining various elements with significant precision and accuracy. This analytical technique is remarkable for its selectivity, speed and fairly low operational cost. However, in some cases there are many difficulties in determining traces of heavy metals in environmental samples due to insufficient sensitivity or matrix interferences. Thus, a pre concentration and/or separation step is necessary.

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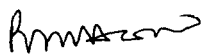
*Specially to Dearest Mom (L) T. Jongwai,
Grand mother B. Jongwai, Dad (L) H.
Bi-am and all family members*

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Declaration

I, Precious Stone Iongwai, do hereby declared that the subject matter of this thesis is a record of work done by me, that the content of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to any body else, and that the thesis had not been submitted by me for any research degree in any other University/Institution.

This is being submitted to the North Eastern Hill University for the degree of Doctor of Philosophy in Zoology.


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(Precious. S. Iongwai)

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General introduction

General information

Geographical distribution

Diagnostic character

Taxonomic Hierarchy

Trace elements in the environment

General information

Most of the species of the genus *Garra* occurs in swift flowing waters of hilly rivers and streams, where they commonly adhere to the surface of underwater gravel and rocky substrates mainly by the adhesive disc modified from the lower lips and also by horizontally extended paired fins.

Garra lamta (Fam: *Cyprinidae*) is predominantly adapted to live in fast flowing turbulent hill streams and river beds comprising mainly rocks, boulders, stones and gravel form a useful hiding and anchoring substratum for the fish. These fishes have 'stone clinging' and 'stone licking' habits and their food mainly consists of algal felts and periphytons, they are known to browse or scrape them off rocks and stones etc. (Anon, 1962; Roberts, 1982; Ojha and Singh, 1992). The ventral lips in *Garra lamta* are evolved as modified structures of skin that border the dorsal, ventral and lateral margins of the mouth covering the jaw bones. Lips may be associated with a specialized adhesive pad or modified as an oral sucker which provides as an admirable device for the adhesion of fish to the substratum (Ojha and Singh, 1992; Singh *et al.*, 1994). In general, lips and structures associated with them are characteristically modified in different group of fishes; these modifications may be associated in some way either with the diet, the method of feeding or with the habit and habitat of the fish.

Garra lamta is also known to feed on epilithic algae and the colour of the body is greenish on the dorsal side and yellowish on the ventral side. The maximum length recorded is about 14.90 cm. The species flourish well at a temperature of 26⁰ to 28⁰ C (Jhingran, 1991; Talwar and Jhingran, 1991; Sen, 1995, 2000; Mahapatra *et al.*, 2003).

Geographical distribution

The genus *Garra* was originally described by (Hora, 1921), from the Siyom river (Brahmaputra river basin) below Damda, among the Abor Hills, India. It has since been recognized as valid (Menon, 1964; Talwar and Jhingran, 1992, Vishwanath, 1993). The known distribution of *Garra lamta* includes China, where it was found in the Yaluzangbu Jiang (Brahmaputra river) in Tibet (Wu and Wu, 1992; Zhang *et al.*, 1995). And both the Longchuan Jiang (upper Irrawady basin) in Yunnan (Chen, 1998; Chu and Cui, 1989).

Garra species are also present in the tropical African and Asian Hill-Stream ranging from Borneo, China, and Southern Asia through the Middle East, Arabian Peninsula and East Africa to West Africa. Most species of *Garra* occurs in swift flowing waters of rivers and mountains streams. So far, seventeen species have been recognized in Africa (Abebe, 1999). At least seven species in Arabian peninsula (Krupp, 1983; Krupp and Schneider, 1989). Approximately twenty species in India, and adjacent countries (Talwar and Jhingran, 1992). Twelve species in South East Asia and eight species in China (Kottelat, 2000). Some species of *Garra* was originally found from Yenping (Nanping), Fukien (Fujian) province of China. And it has so far been described by Chinese Authors as valid species extensively known from the upper Irrawady, upper

Mekong river basin as well as Hainan island. However *Garra orientalis* and *Garra lamta* was considered by Menon, (1964), as a widely distributed species with a range extending from Assam from India to Southern China and Northern Vietnam. Kottelat, (2000), recently indicated that the material from the Salween, Mekong, and red river basin is distinct from the species found in Assam, India.



Fig. 1. *Garra lamta*

Fig.1. *Garra lamta*

Diagnostic character

The surface architecture of the structure associated with *Garra lamta* have been described by Roberts, 1982 and Singh *et al.*, 1994. In this teleost fishes the lips are inconspicuous and associated with a prominent horny jaw sheaths. Furthermore, the upper and lower lips are associated with a greatly enlarged rostral cap and an adhesive pad respectively. The rostral cap has a proximal mucogenic region and distal keratinized

region. Lips are evolved as a modified structure of skin that borders the dorsal, ventral and lateral margins of the mouth covering the jaw bones.

In *Garra lamta* lips may be associated with a specialized adhesive pad or modified as an oral sucker which provides as an advice for the adhesion of fish to the substratum, (Benjamin, 1988). In this species the mouth is sub terminal and situated on the ventral side of the head. The upper jaw and the lower jaw are slightly protrusive. The epithelia covering the major distal regions of the upper jaw and the lower jaw are characteristically modified into conspicuous Horny Upper Jaw Sheath (HUJS) and Horny Lower Jaw Sheath (HLJS) respectively. The upper and lower lips are inconspicuous and appear as slight thickenings or small stumpy papillae like structures, at the narrow area of the epithelia covering the proximal regions on the dorsal side of the upper jaw and the ventral side of the lower jaw respectively.

The dorsal side of the upper lip is associated with the rostral cap through a thin and extensive fold of skin which lies in a deep groove. The rostral cap is greatly enlarged and its apical end greatly extends ventrally overlying and concealing the upper lip and partially shielding horny upper jaw sheath. The surface of the rostral cap may be divided into two distinct regions-a major proximal region towards the dorsal head skin, and a narrow distal region towards the mouth opening.

The lower lip on its ventral side is associated with a specialized structure the adhesive pad through a thin fold of skin. The adhesive pad is characteristically large and rounded structure that appears like a shallow plate divided into a major central region and

relatively narrow peripheral region. The peripheral region of the adhesive pad at the anterior side is more conspicuous and well developed than the posterior and lateral sides and shields the lower lip. The central region of the adhesive pad is separated from the ventral head skin through a deep cleft lined by thin fold of skin, (Whitear and Moate, 1994). Fish identification was done following identification keys with the help of ZSI (Zoological Survey of India) standard literature.

Taxonomic Hierarchy

Kingdom	-	Animalia
Phylum	-	Chordata
Sub phylum	-	Vertebrata
Super class	-	Osteichthyes
Class	-	Actinopterygii
Sub class	-	Neopterygii
Infra class	-	Teleostei
Super Order	-	Ostariophysi
Order	-	Cyprinoformes
Super family	-	Cyprinoidea
Family	-	Cyprinidae
Genus	-	<i>Garra</i>
Species	-	<i>lamta</i> (Hamilton, 1822)

Trace elements in the environment

Trace elements in aquatic environment occur naturally from weathering of rocks and mineral soils and from human activities such as the burning of fossil fuels, industrial discharges, mining, agricultural pesticides and fertilizers. Historical and current mining practices are believed to affect the quality of aquatic ecosystem and aquatic life (Tornes, 1997; Beckwith., 1998). Many trace elements especially Cu and Zn are essential to animal and plant nutrition but can be toxic in high concentration. Cu, and Zn are some of the more notable elements found to be toxic to aquatic life in higher concentration (Eisler, 1988). Aquatic organisms have developed mechanisms to regulate internal concentrations of certain trace elements in tissues or to mitigate their toxicity (Law, 1996). Trace elements concentrations in tissues of aquatic species generally increase with increasing age, body size and trophic status. (Parks and Curtis, 1997).

Concentration of trace elements in fish sample provide a time-integrated assessment of contaminant and a better understanding of the complexities of the distribution, and effects of various trace elements (Crowford and Louma, 1993). Trace elements can be ingested with stream bed sediment in the water column by benthic organisms and can accumulate and move through the food chain. Fishes are particularly good indicators of biologically available contaminant, because environmental contaminants can accumulate in their bodies at higher concentrations than in surrounding waters. Many trace elements concentrate in the viscera of fish such as liver and kidneys (Goldstein *et al.*, 1996). The concentration of trace elements may vary

depending on the number of factors such as the chemical properties of the elements and the fish species.

The uptake and accumulation of trace elements by organisms depends on many factors including physical and chemical form of the elements in the environment, the biological needs for specific elements or its homologue by the animal, seasons and other climatic factors such as temperature, the age of organisms, the specific tissues involved and the specific characteristic of the local ecosystem. Biological uptake is associated with metabolism which is dependent on body size, age, sex, physical conditions, metabolic rate and deposition of stable element where accumulation occurs. Hence to understand the bio accumulation and distribution of selected trace elements in this species the study was conducted under natural conditions.

Aquatic ecosystem receiving mine wastes often becomes severely polluted, even with small flow of polluted water. The literature review indicate a number of studies on the effects of continuous discharge of mine wastes into rivers, flora and fauna of these rivers suffer from various types of pollution at the individual, community and the ecosystem level.

In recent years, there has been a growing concern over the increase in heavy metal contamination from different sources such as automobiles and industries affecting the terrestrial and aquatic environments and ultimately their biological affect on man (Dussart, 1984). The released of pollutants, especially heavy metals, into the aquatic

environment via water runoff is known to cause detrimental effects to the receiving environment (Borchardt and Sperling, 1997). Most heavy metals entering water bodies become associated with particulates and as a result of settling time, accumulate in the bottom sediments of the receiving water (Nix *et al.*, 1988). However, re suspension may occur allowing the mobility and bioavailability of these contaminants (Diks and Allen, 1983).

Chemical weathering is also of fundamental importance for different ecosystems since many essential biochemical elements are derived from the underlying rocks (Schlesinger, 1991), and it contributes macro nutrients such as Ca, Mg, K as well as micronutrients such as Fe and Mn. Not only are terrestrial ecosystems heavily dependent on chemical weathering, but the rivers as well. The dissolved solids carried by small streams entering the rivers are a major source of several elements in the rivers (Whitfield, 1981). Another important feature of chemical weathering is its ability to neutralize acids. There are several sources of acids in the environment, natural as well as anthropogenic. In an acidified environment the solubility and mobility of several elements are enhanced (Berner, 1995).

The long-term monitoring of anthropogenic pollution in aquatic ecosystems is of environmental and human health concern nowadays, when numerous effective measures were undertaken to reduce the pollution impact on natural water bodies. In these studies aquatic organisms are widely used for biological monitoring of variations in the environmental levels of anthropogenic pollutants, (Phillips, 1980; Hellowell, 1986).

Among aquatic indicator organisms a significant role is assigned to fishes due to their significant capacity to accumulate heavy metals, assemblages, and their essential role in the enrichment of anthropogenic compounds in food chains, (Stemberger & Chen, 1998).

It is clear that the susceptibility of biological communities to trace element contamination differs among aquatic environments. One important reason is that the bioavailability of metals in sediments appears to be altered by variations in sediment geochemistry. However, methods for explaining or predicting the effect of sediment geochemistry upon metal bioavailability are poorly developed. Experimental studies demonstrate that ingestion of sediments and uptake from solution may both be important pathways of metal bioaccumulation in deposit or detritus feeding species. Relative importance between the two is geochemistry dependent.

Geochemical characteristics of sediments also affect metal concentrations in the tissues of aquatic organisms, but the specific mechanisms by which these characteristics influence metal bioavailability have not been rigorously demonstrated. Several prerequisites are necessary to better understand the control of metal bioavailability from sediments. It is well established that detectable trace metal contamination occurs in many aquatic environments as a result of human activities. The biological impacts of that contamination are still poorly understood. This is partly because the processes that control accessibility of metals to aquatic biota (i.e. the biological availability of metals) are poorly understood, (Luoma and Bryan, 1982).

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A review of the literature reveals that little attention has been paid to the study of trace elements in this species (*Garra lamta*). The purpose of this study was to assess the concentration of selected trace elements (Mn, Fe, Cu, Ni, and Zn) in whole body tissue of *Garra lamta*. Furthermore, Correlation among the selected metals and accumulation in the fish body were determined. Fishes are ideal indicators of heavy metals contamination in aquatic ecosystems, and they are unique among the vertebrates because of their potential for trace element acquisition from the water body, (Bury *et al.*, 2003). Contamination alters their health, size, and age structure. Some trace elements accumulate in tissues and may pose a health risk to those who frequently consume fish, evaluation of these effects is important from four points of view- toxicology, ecological, human health and breeding, (Bury and Grosel, 2003).

Trace elements in Fish samples

Literature survey reveals that these types of investigations are carried out by Zoology Department, Monash University Clayton, Australia. The reported work on heavy metal estimation in Australia has been reviewed. The great bulk of this work has been concerned with obtaining information on heavy metal concentration in waters and biota, with the emphasis on the biota being often to allay public health concerns. There are few data on the effects of heavy metals on Australian biota and that available mostly relates to laboratory-base toxicity studies. Very few data are available which relates to the processes controlling the behavior of contaminating heavy metals with the Australian



environment, that is their speciation, transportation, transformation from one compartment to another and their ultimate fate (Ahsanullah *et al.*, 1981). This lack of any adequate process understanding of contaminating heavy metals is of particular concern in Australia because of the quite distinctive features of many Australian aquatic ecosystems (certainly the fresh water ones). This distinctiveness makes the relevant of overseas data relating to the effects of heavy metals on many Australian aquatic ecosystems. (Ahsanullah and Arnott, 1978).

These studies review the current state of knowledge relating to heavy metals in the Australian environment, with particular emphasis on the aquatic environment. This emphasis arises for two reasons. First, the area of research is relating to aquatic ecosystems, and second there is a paucity of data on heavy metal contamination of Australian terrestrial ecosystem. The main aim of these studies was to review the sources of heavy metals entering the Australian aquatic environment and their levels in various compartments particularly biota and water bodies. To understand the biogeochemical cycling of heavy metals taking into consideration their speciation, transportation, transformation, mobilization and their fate. It also aims to study the effects of heavy metals on Australian ecosystem taking into account laboratory toxicity studies at population, community and ecosystem levels, (Ahsanullah, 1976).

Review of literature also shows that similar type of work have been done by U.S. Fish and Wildlife services Arizona (Ecological Services Office) and U.S. Fish and Wildlife Services Corpus Christi, Texas. In these studies fish samples were collected

from Imperial, Cibola and Havasu National Wildlife Refuges (NWR) in 1988-89 to assess levels and potential effects of trace elements on fish and wildlife of the lower Colorado River. In these studies thirteen trace elements were detected in fish tissues, they have found out that Copper concentration was extremely at elevated level of 18.8 ppm wet weight in Carp samples from Martinez Lake. This concentration was about eight times greater than the next highest level in fish from any of the three sites, and was similar to the highest Copper concentration of 23.1 ppm wet weight detected during the 1976-84 by NCBP (National Contaminant Bio-monitoring Programme) sampling, (Schmitt and Brumbaugh, 1990).

Nickel was discovered in all samples from Martinez Lake and in one from Cibola Lake. Nickel concentration >0.99 ppm wet weight in fish can be considered elevated in relation to unpolluted sites studied by the service. However the level recorded in these studies was 0.4 ppm. The potential for bioaccumulation of nickel also is not well known. Iron and Manganese were found to present in whole body samples and their concentration is 3.1 ppm and 24.6 ppm respectively. Backgrounds for these trace elements in fish and their propensity to bio accumulate through the food chain are not well known, (Irwin, 1988).

These types of investigation are also carried by the National Institute of Freshwater Fisheries Research and the Department of Chemistry, Federal University of Technology Nigeria. In this study the level and distribution of Copper, Zinc and Cobalt in five commercially important fishes in Lake Kainji, Nigeria were determined using

standard methods. The range of these trace metals in fishes (*Tilapia spp.*) were: Copper 0.23-2.93 ppm, Zinc 15.5-36.8 ppm, and Cobalt 0.04-0.27 ppm. Lake Kainji is the largest man-made lake in Nigeria with surface area of 1270 km². There are 104 different species of fishes, with a diversity index of 0.91 when compared with other inland reservoirs in the Country, (Ita, 1993). Following the impoundment of river Niger at Bussa in the early 1960, there was a glut in the lake Kainji fishery, which attracted a lot of fishermen both from Nigeria and neighboring countries. Consequently, there were a lot of human activities along the lake. Fisherman and their families were dependent on the lake fishery as their means of livelihood. Effluents from domestic activities found their way into the lake. Furthermore, the activities of the hydroelectric power plant also constitute effluents to the lake. This study reveals the distribution of heavy metals in various fishes of economic importance and the water body in three different locations in lake Kainji with allowable limits of protection of aquatic life and human consumption. (Biney and Beeko, 1991).

In addition to routine contaminant, an aggressive bio assessment initiative is needed to determine the viability of fish populations in fresh water and riverine habitat. Special emphasis should be place on determining if reproduction is occurring in fresh water areas. It should also be determined if toxicity is associated with areas of sedimentation and on-site bio accumulation connected with the life histories of species primarily residents in fresh water habitats. On the basis of human health concerns, continued monitoring of fish commonly caught for consumption is most urgent. While these studies focused on fresh water areas where contaminant level was suspect to be

highest, future monitoring should include all regularly fished waters. Monitoring efforts should be expanded to include waterfowl wintering on refuge lands.

Trace elements in water samples

Literature survey on trace elements in water samples shows that a lot of work has been done on this field by Environmental Protection Agency, Stockholm, Sweden. In this study heavy metals in running water are analyzed in the Swedish surface water at about eighty stations, data for selected rivers and brooks has been used to assess the effect of soil acidification on the concentration of metals in these water bodies, (Andersson *et al.*, 1991).

In Southern Sweden acidification shows a significant effect on Zinc. In the upper parts of the drainage areas, there is a marked increase in the leakage of these metals from soil to water indicated by elevated concentration of Zinc in brooks and also by high maxima during periods of low pH values. The increased leaching from forest soils also influences the concentrations in rivers in Southern Sweden. During periods of high water flow, the pH values of the rivers decrease and the concentration of Zinc increases. At pH levels of 6.2-6.5 the concentrations of Zinc are mostly two to five times higher as compared to pH levels of about seven. Since high concentrations of Zinc coincide with high water flow, the transport of metals has most certainly increased several times compared to the pre-industrial periods, (Johansson *et al.*, 1995).

Heavy metals in running waters mainly originate from soils in the drainage area. In forest soil the content of mobile metals is the result of weathering and natural circulation within the forest ecosystem, but also for some metals from anthropogenic atmospheric deposition. In Sweden the concentrations of heavy metals in the forest soil display a large scale pattern, with the highest levels being recorded in the South-West of the country. Anthropogenic acidification of forest soils increases substantially the leeching of some metals to inland waters. This is especially true for metals like Zinc and Aluminium, (Bergkvist *et al.*, 1989; Verta *et al.*, 1990).

Heavy metals like Copper, Iron, Zinc and Manganese are analyzed within the Swedish Surface water Monitoring Programme at about eighty stations. In addition, data for about twenty other water quality variables, as well as data on water fluxes are also available. These data are representative of the water quality in Swedish running waters and can be used for a large variety of evaluations. The aim of this study is to use the data for appropriately selected water courses and to evaluate possible effects of acidification of metals on running water.

The store of heavy metals in the soil is very large compared to the annual flow through the terrestrial compartment. In Sweden, for most metals less than one percent of the content in the surface soil is released annually by run-off waters, (Johansson *et al.*, 1995). Hence, even small changes in solubility due to acidification will have a significant effect on the leakage to running waters, especially for metals weakly bound to soil particles.

Abiotic parameters

A lot of work has been done on the abiotic parameters of freshwater ecosystems. Study by the National Research Institute of Aquaculture, Tochigi, Japan shows that low pH exposure effects gametogenesis and embryo development of adults Salmonids. A highly acidic environment directly kills embryo, larvae and juveniles of Salmonids fishes, (Rambough, 1988). However, some fish populations may sustain damage when the acidic environment affects the reproductive activities of mature fish in the early stages of the acidifying processes or as a result of exposure of adults to low pH. Vourinen *et al.*, (1992) reported that the breeding season of perch, which is an acid tolerance teleost species, was delayed in acidic lakes. Brook trout avoid acidic environments in the selection of spawning site. These observations and others suggest that acidification of the environment is a negative factor affecting the reproductive process in fish.

Tam and Payson, (1986), reported that acidification inhibited vitellogenesis and ovulation of the oogonia in Salmonids, resulting in the delay of spawning and atresia of the ovary. Weiner *et al.*, (1986) reported that development, hatching, and yolk-sac absorption were reduced in eggs stripped from acid- exposed female rainbow trout. These result suggest that acidification of adult fish affects not only the maturational process of the gonads, but can also indirectly affect survival of their progeny. This study indicates critical level of pH in teleost fishes may exist between 5.5 and 4.5.

Review of literature reveals that a lot of work has been done on dissolve oxygen in fresh water in order to protect aquatic ecosystems. Liquid wastes discharged into

surface waters are required to have a high level of dissolve oxygen (5 mg/l) this is often a legal requirement enforced by means of effluents standards. If waste waters do not fulfill this requirement they have to be treated. Continuous exposure of fish to dissolve oxygen levels between 1 to 5 mg/l can slow down their growth, while levels below 1 mg/l are lethal to fish if exposure lasts more than a few hours.

The present of dissolve oxygen in waste water is desirable because it prevents the formation of noxious odours. Very high levels of dissolve oxygen are to be avoided in domestic and industrial water supplies in order to minimize corrosion of iron and steel pipes in the distribution system. Most countries do not set a dissolve oxygen standard for drinking water with the exception of Russia, which set a maximum allowable concentration (MAC) of 4 mg/l for drinking water. For fisheries and aquatic life the following dissolve oxygen standard have been adopted: Canada 5.0-9.5, Russia 4.0-6.0.

Literature survey on alkalinity in fresh water ecosystem reveals that a lot of work has been done on this field. Alkalinity is a measure of the concentration of alkaline material in the water body and the capacity of water to accept any acidification without impacting the pH too much. The ideal range of alkalinity for fish life is 20-300 mg/l. If alkalinity is below 20 mg/l the water will be extremely soft and will have a very low buffering capability and thus pH will vary a great deal. Any acids finding their way into the water (for example after heavy rain), will cause a big fall in pH. Such fluctuations of pH are harmful to fish since all fish prefer stable and non-stressful situations. Water with low alkalinity can be treated with lime, many pond keepers place shells inside filters to

increase alkalinity. High alkalinity levels can sometimes lead to a condition in the fish called nephrocalcinosis (high calcium concentrations in the kidneys). Literature survey on temperature in fresh water ecosystem reveals that a lot of work has been done on this field. Indian rivers are home to danios, spiny eels, carps and teleost etc, which flourish well at a pH of 7.0-7.7 and a temperature of 21-24⁰C.

Reproductive strategies

The study of reproductive strategies and the assessment of fecundity are fundamental topics in the study of the biology and population dynamics of fish species. Studies on reproduction, including the assessment of size at maturity, fecundity, duration of reproductive season, permit quantification of the reproductive capacity of individual fish. This information in combination with estimates of egg production enables estimation of spawning stock biomass, (Saville, 1964; Parker, 1980; Lasker, 1985). This increases our knowledge about population dynamics and improves standard assessment of many fresh water fish species. Moreover, establishment of extensive data bases on reproductive parameters with corresponding data on abiotic factors enables the study of causal relationships between reproductive potential and environmental variations, this lead to a better understanding of observed fluctuations in reproductive capacity, (Kraus *et al.*, 2002).

Only few workers have been studied the fecundity of some species of fish. (Doha and Hai, 1970; Karim and Hossain, 1972; Shafi and Mustafa, 1976). In case of fresh fish *Mystus tengra*, some aspects of biology, fecundity and taxonomy have been reported by

Khan *et al.*, (1992). The study on the fecundity of this species was conducted with a view to assess danger if any to its population due to the indiscriminate capture of ovigerous females and in addition to contribute some information for more intensive research work on this fish. One of the main goals of estimating fecundity is to establish a fecundity-size (Length/Weight/age) relationship, which can be used to scale estimate of spawning stock or spawner abundance to population egg production. For this purpose, it is very important to ensure that the entire length range of females present in the population is covered providing consistent sampling among sub components over years. This is best achieved through length stratified sampling over the stock's entire size distribution.

Marked differences in fecundity among species often reflect different reproductive strategies (Pitcher and Hart, 1982; Wootten, 1984; Helfman, *et al.*, 1997). Within a given species, fecundity may vary as a result of different adaptation of environmental habitats (Witthames *et al.*, 1995). Even within a stock, fecundity is known to vary annually under long term changes (Horwood *et al.*, 1986; Rijnsdorp, 1991; Kjesbo *et al.*, 1991), and has been shown to be proportional to fish size and condition. Larger fish produce more eggs both in absolute and in relative term to body mass. For a given size, females in better condition exhibit higher fecundity (Kjesbo *et al.*, 1991). Fish size and condition are thus key parameters to properly assess fecundity at the population level.

Fecundity is an important variable in life-history studies because it is a major component of fitness (Stearns, 1992). Knowledge of the relationships between age-

specific life history traits (annual fecundity, egg size, growth, mortality) is vital to understand the natural role. In some situation fecundity not only declines as a consequence of the reduce abundance of spawners, but also due to the disproportionate in large highly fecund females, fecundity may vary annually within individuals. Changes in environmental factors, such as temperature, may affect condition by influencing fish behavior and metabolism. Decline in fecundity due to reduced condition can be reflected in a lower number of oocytes that develop in a given breeding season or through atresia. In extreme cases, low condition can induce reproductive failure and lead to skipped spawning seasons (Bell *et al.*, 1992; Livingstone *et al.*, 1997). Fecundity and atresia can also be affected by environmental pollution (Johnson *et al.*, 1998).

Studies on the population dynamics of both lacustrine and riverine fish species, especially those of temperate regions are common (Welcomme, 1985). Where as such studies on tropical stream-dwelling, small size species, especially from Asia are few. Among such studies from tropical Asia are those of Balon, (1981) in some streams of Thailand and in some streams of northern Borneo. The study of fish populations of fresh rivers and streams particularly that of small size species has a practical value as well, since such species if present in abundance could provide a supplementary source of proteins.

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Experimental Chapters

Chapter-1

Quality control of the analytical data

Instrumentation

Description of the study area

Introduction

The validity of the analytical methods for determination of trace elements in fish sample was done through quality assurance programmes. The quality controls of the data was done through analysis of standard reference materials, replicate analysis, cross method checks and inter comparison studies. The accuracy of the method cannot be determined since the “true” value is unknown. One way to assess accuracy of the method is by analyzing *reference materials*. Reference materials are actual samples which have been carefully analysed by a government laboratory (Ankley *et al.*, 1996; Baines *et al.*, 2002; Baldwin *et al.*, 1994). Concentrations of various analytes in the samples are reported and the materials is said to have been *certified* when accompanied by a certificate. These are called *certified reference materials* (CRM) and they can be purchase from Government laboratories, e.g. International Atomic Energy Agency (IAEA), Vienna. Laboratory of the Government Chemist (LGC), United Kingdom, etc. (Batley, 1987).

Results and Discussion

The analysis of trace elements in fish samples was carried out in standard reference materials of fish sample provided by International Atomic Energy Agency (IAEA), Vienna. Fe, Zn, Mn, Cu, Ni, and Co was analyzed in Fish (IAEA-407) samples. The observed concentrations of trace elements along with certified levels are summarized

in Table. 1.1 and Fig. 1.1 & 1.2. It is evident from the table that the observed values vary within $\pm 7\%$ of the certified values.

Reference material	Elements	Observed value (mg/Kg)	Certified value (mg/Kg)
IAEA-407 Fish samples	Co	0.097 (0.094-0.983)	0.1 (0.09-0.11)
	Cu	3.33 (3.29-3.35)	3.28 (3.20-3.36)
	Fe	147.4 (145-150)	146 (143-149)
	Mn	3.55 (3.51-3.59)	3.52 (3.44-3.60)
	Ni	0.63 (0.59-0.65)	0.6 (0.55-0.65)
	Zn	67.5 (66.4-68.2)	67.1 (66.32-67.9)

Table: 1.1

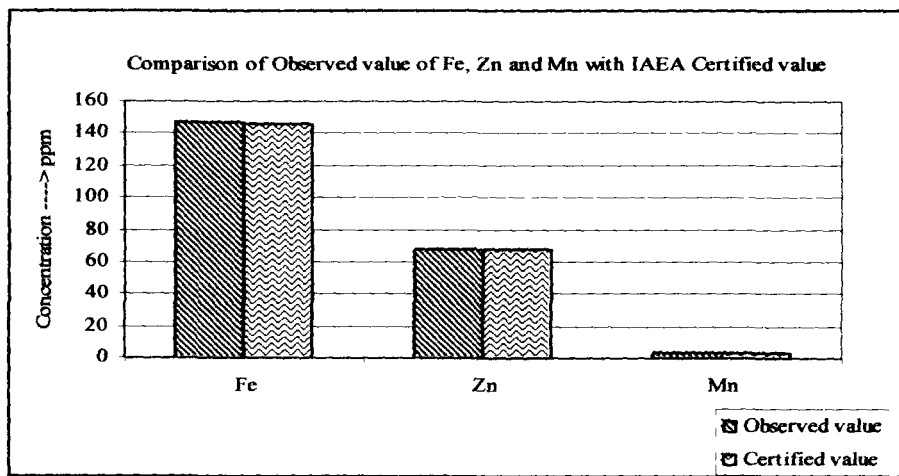


Fig: 1.1. Comparison of observed value of Fe, Zn and Mn with IAEA Certified value

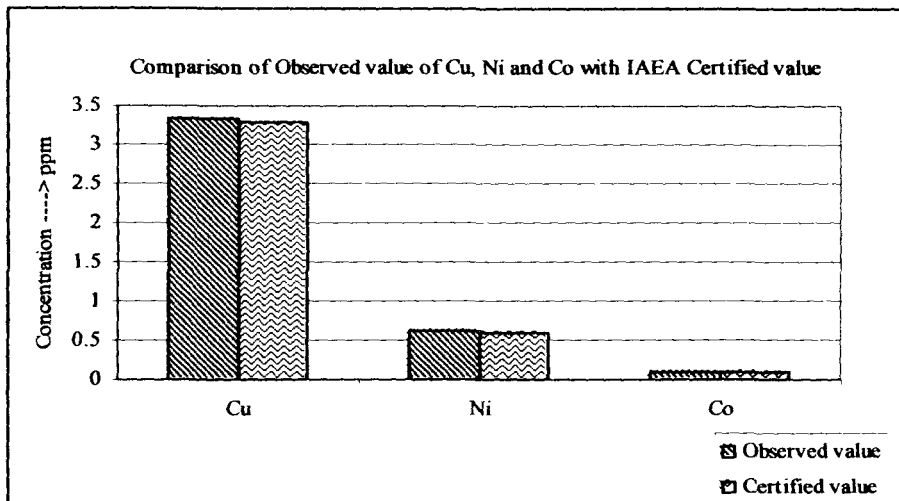


Fig: 1.2. Comparison of observed value of Cu, Ni and with IAEA Certified value

The quality control of the data generated for trace elements analysis in water samples was assured through inter comparison studies carried out between different institutes. An inter comparison study for the estimation of trace elements was carried out between AMD, Shillong and EAD, BARC, Mumbai. The analytical techniques used for analysis at AMD and BARC were AAS (Atomic Absorption Spectrophotometer). The estimated trace elements concentrations in spiked water samples are given in Fig. 1.3 to 1.6. It is evident from the result obtained that there is a good correlation between different laboratories.

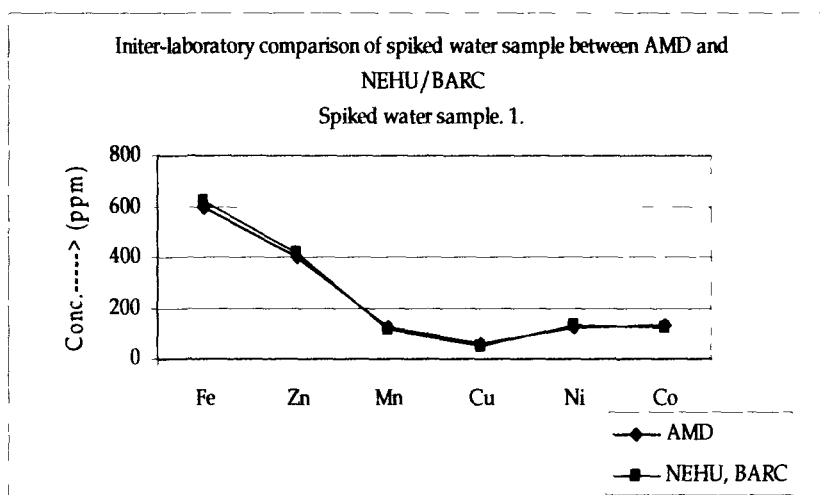


Fig: 1.3. Spike sample 1

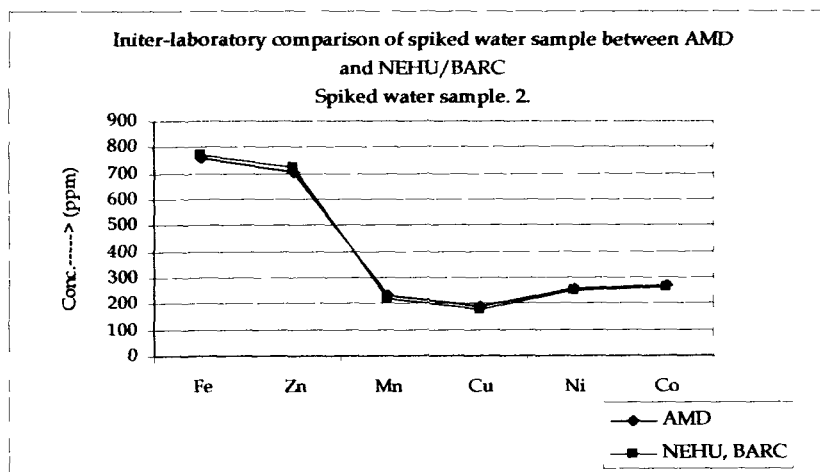


Fig: 1.4. Spike sample 2

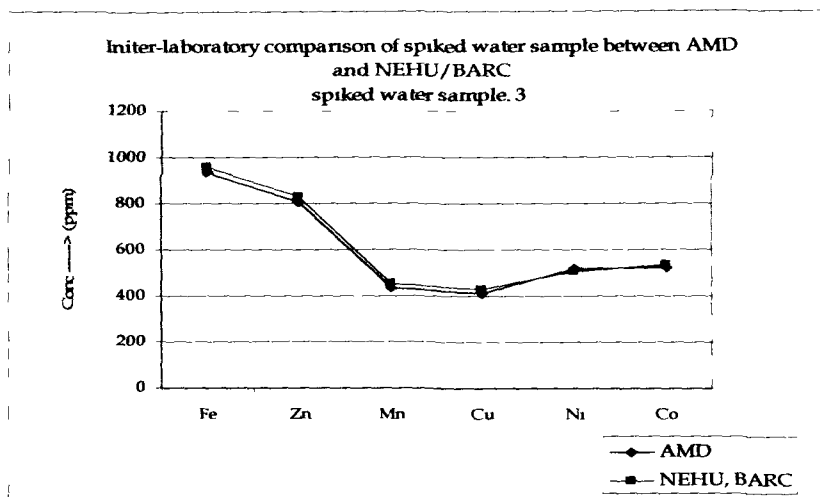


Fig: 1.5. Spike sample 3

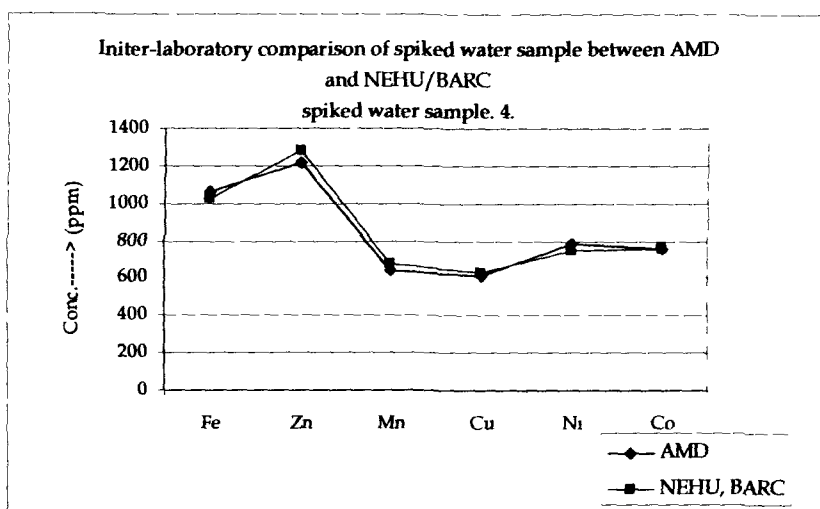


Fig: 1.6. Spike sample 4

****Note:** Figures 1.3 to 1.6 (Graphical representation of inter-laboratory comparison of spike water samples)

Instrumentation and Calibration

The technique of Atomic Absorption developed by S. Allan Walsh in the mid 1950 has become the preferred method of elemental analysis. Walsh discovered that the majority of free atoms in the commonly used flames were in the ground state, but that the flame did not have enough energy to excite these atoms (except for the group I elements).

A light source emitting a narrow spectral line of the characteristic energy is used to excite the free atoms formed in the flame. The decreased in Energy (Absorption) is then measured.

The absorption is proportional to the concentration of free atoms in the flame, given by the Lamberts Beer's law

$$\text{Absorbance} = \text{Log}_{10} I_0/I_t \propto K.C.L.$$

Where;

I_0 = Intensity of incident radiation emitted by the light source

I_t = Intensity of transmitted radiation

C = Concentration of sample (free atoms)

K = Constant (can be determined experimentally)

L = Path length.

Atomic-absorption (AA) spectroscopy uses the absorption of light to measure the concentration of gas-phase atoms. Since samples are usually liquids or solids, the analyte atoms or ions must be vaporized in a flame or graphite furnace. The atoms absorb ultraviolet or visible light and make transitions to higher electronic energy levels. The analyte concentration is determined from the amount of absorption. Applying the Beer-Lambert law directly in AA spectroscopy is difficult due to variations in the atomization efficiency from the sample matrix. Concentration measurements are usually determined from a working curve after calibrating the instrument with standards of known concentration.

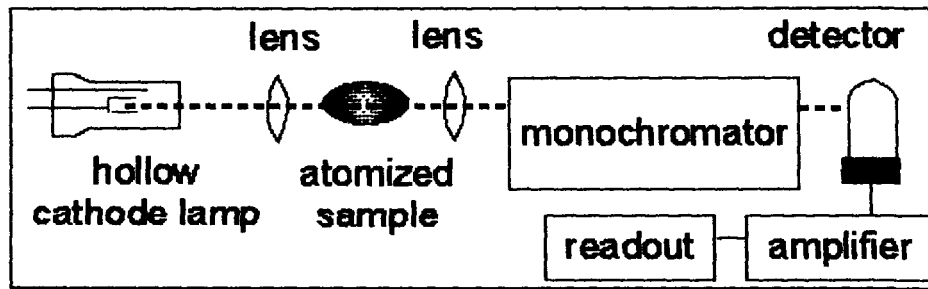


Fig: 1.7. Schematic diagram of an Atomic-Absorption Spectrophotometer

Calibration

Most modern Atomic Absorption instruments include microcomputers-based electronics. The microcomputer provides atomic absorption instruments with advanced calculation capabilities, including the ability to calibrate and compute concentrations from absorbance data conveniently and accurately. One standard and a blank may be sufficient for defining the relationship between concentration and absorbance. However, additional standards are usually used to verify calibration accuracy.

The calibration is performed using the most common method where interference effects are known to be absent. Usually at least three (3) standards and a blank are used to cover the range 0.1 to 0.8 absorbance. The calibration is performed by using the blank solution to zero the instrument. The standards are then analyzed with lowest concentration first and the blank run between standards to ensure the baseline (Zero point) has not changed. Samples are then analyzed and their absorbance is recorded.

Description of the study area

The study area is located in south western part of West Khasi Hills District Meghalaya (N25°16'30"; E91°16'15"), India. It is about 160 kms from Shillong. The area has a very rugged and dissected topography. The sampling site is much closed to Domiasiat-Mawthabah area approximately at a distance of 2-4 kms this area has been identified as one which has a heavy deposit of uranium ore. Here the existence of sandstone type of uranium ore has been reported by the Atomic Minerals Division North Eastern Region (AMDNER), Government of India, (Dhana *et al.*, 1989).

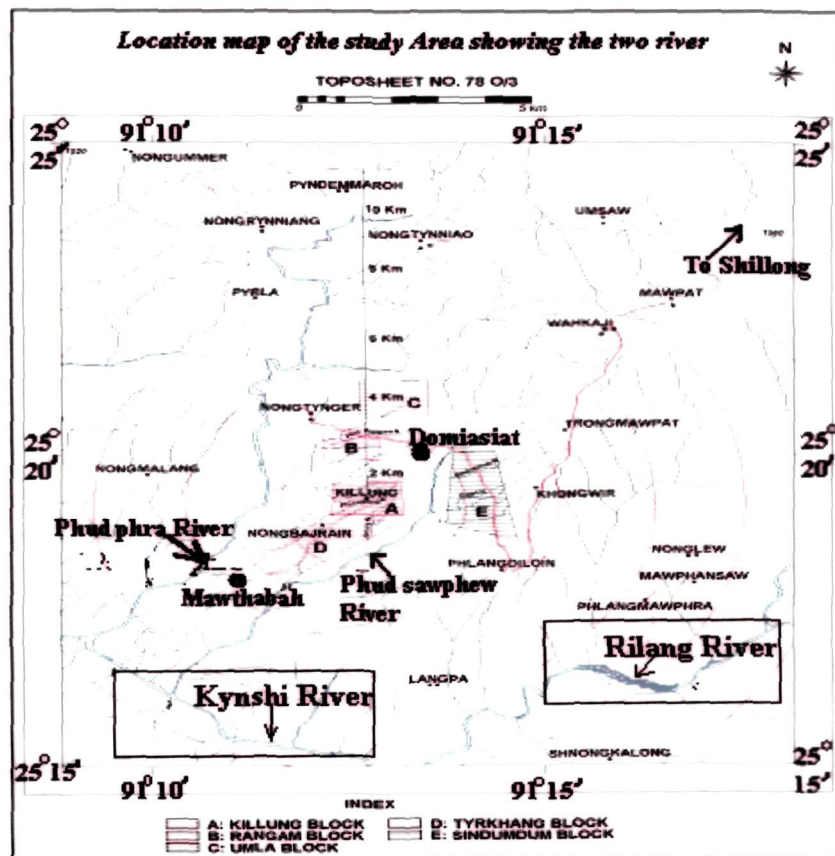


Fig: 1.8. Map showing sampling sites

Domiasiat located on the southern slope of Meghalaya plateau is connected with Shillong via Mawkyrwat and Wahkaji by road. Wahkaji to Domiasiat is 10 km linked by kutcha road. The general elevation of the area ranges between 500 and 1070 m above sea level. Physically the area is a gentle southward dipping plateau with deeply cut gorge sections of Umsohphie and Wah Phudphra rivers on either side. The first and second order streams are controlled by the gentle south Western slope while the higher order streams are controlled by basement structures. The general flow of the drainage in the area is towards south west towards Bangladesh. The area receives heavy rainfall, being about 1000 cm per annum, same as that of Cherrapunjee, the temperature ranges between 3 and 33⁰C. The plateau is covered with scanty vegetation consisting mainly of shrubs and bamboos, whereas the course of various streams is highly wooded. A small shrub *Elatostemma rupestrewedd* is commonly found in the vicinity of mineralized zones (Ravi and Verma, 1990).

The southern fringe of the Meghalaya plateau composes of Precambrian gneissic complex. In West Khasi Hills the fluvial lower Mahadek (Mainly grey sandstone) increase in thickness from south to north, but in the East Khasi and Jaintia Hills area there is thick marine facies in the south and thinner fluvial. The study area mostly comprises lime stone-sandstone and argillaceous intercalations indicating shallowing of the basin. The entire sedimentary succession dip gently towards south. The sediments are the thickest in the southern part and slowly peter out in the north. Overlapping by the younger sediments of the old ones, alternation of the arenaceous and calcareous sedimentary facies and deposition of certain sedimentary units and their lithic variations

indicate transgression in the basin and relative movement with the basin development (Sengupta *et al.*, 1991).



Fig: 1.9. On the way to sampling sites

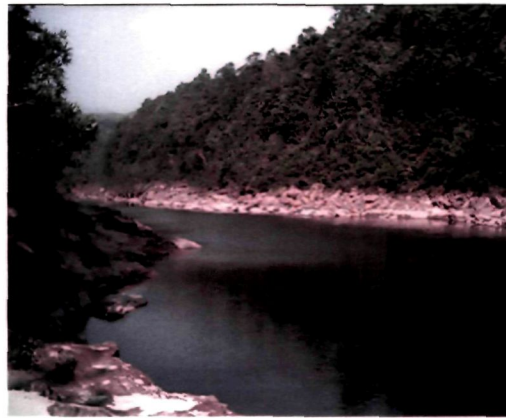


Fig: 1.10. Sampling sites (a)

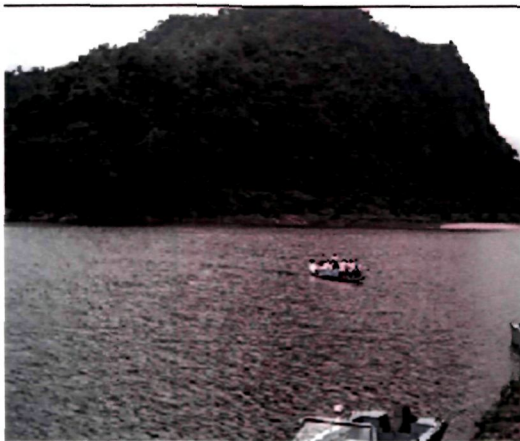


Fig: 1.11. Sampling site (b)



Fig: 1.12. Sampling site (c)



Fig: 1.13. Sampling site (d)



Fig: 1.14. Sampling site (e)

Lower Mahadek sandstones are the host for Uranium mineralization in Domiasiat area. These directly overlie basement granites and gneisses. In general, lower Mahadek sediments range in thickness from 40 to 60 m. Cross bedding, both tabular and trough types, together with cut and fill structures indicate the fluvial nature of the sediments with overall transport of the clastics from north to south. The discovery of Uranium occurrence measuring two bands of 80 m each along the strike near Alukwadi on Ranikor-Maheshkhola road was a turning in the exploration history of Mahadeks. Areas lying north of Gomaghat across the river Kynshi were surveyed by rapid radiometric checking around Phlangdiloin in 1979-80 and 1982-83 field seasons. Fairly extensive mineralization at shallow depth associated with organic matter was in lower Mahadeks around Nongmalang-Domiasiat-Mawthabah areas. Most significant being the occurrence in the Kyllung nala section approximately 2.5 kms south of Domiasiat. Grab samples from this zone assayed 0.01 to 0.82% U_3O_8 (Sunil *et al.*, 1990).

The river Kynshi originates from northern part of West Khasi Hills District of Meghalaya and flows to the south towards Bangladesh. The confluence of the three rivers viz. Kynshi, Wahblei and Rilang together give rise to the river Jadukata. The river system is connected with many smaller rivers and streams. In West Khasi Hills the river system consists of fast flowing rivers and streams and is home to many endemic and endangered fishes. Similarly it harbours many endangered and commercially important species. The river system and streams are characterized by shallow, narrow channels with rocky beds and swift turbulent water flow.

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Chapter-II

(Seasonal variation of trace elements in Garra lamta from Kynshi River)

Introduction

Metals occur naturally in aquatic systems and accumulate in the tissues of aquatic organisms (Bury *et al.*, 2003). When additional sources of metals from polluting industries enter these systems, aquatic organisms can be exposed to concentrations that are deleterious. The effects on organisms can range from acute mortality to chronic effects such as reductions in growth and reproduction output (Weis *et al.*, 2002). The consequences of these biological effects can be profound, reductions in productivity and biodiversity, changes in the structure of biological communities, and effects on human health have been observed in various locations (Lemly, 1993, 1999).

Materials and Methods

A sample is that portion of the physical environment which is withdrawn for chemical analysis. A sample can be aqueous (e.g. river water), or solid (e.g. fish or soil). The chemical substance being analyzed in the sample, whether an element, ion or compound, is referred to as analyte (e.g. zinc in water). Sampling is the process by which a sample is obtained and this is done as follows:

Fish samples (*Garra lamta*) are collected on a monthly basis over a period of two years for the year 2003-2004 and 2004-2005. The method of fish catching are done following the indigenous method of fishing that is netting, netting of fish is mainly of

four types trapping net (Langi), casting net (Jal), bamboo sieve type net (Jakha) and throwing net (Achara). Once collected, the samples are preserve in 5% formalin and transported to the laboratory, it is then stored in the refrigerator at 4⁰C until analysis can be performed. The length of time for which samples can be stored varies, depending on the analyte, the sample are analyzed at the earliest convenient time.

Organic content of the fish sample is destroyed by ashing in a muffle furnace at temperature of 400⁰-500⁰C for 24 hours and ash weight was recorded, the ash sample were digested in perchloric acid (HClO₄), concentrate nitric acid (HNO₃) (electronic grade) and Hydrogen fluoride (HF) 2ml each. It is then evaporated nearly to dryness, 10ml of 0.25% HNO₃ was added and filter though Whatman 542 filter paper, the residue are washed with another 10ml of 0.25% HNO₃ and the final volume are made up to 25ml by the addition of 0.25% HNO₃. The extract was analyzed using Atomic Absorption Spectrophotometer (AAS) at Sophisticated Analytical Instrumentation Facility (SAIF) NEHU, and Environmental Assessment Division, (EAD), BARC Mumbai.

Some quite sophisticated statistical sampling procedures have been developed that can help to perform the experiment correctly. Sampling should usually decide on the best location, time and number of samples to be taken (so-called random sampling). Consideration of site accessibility, time and expense are often more influential factors.

Statistical Analysis: One-Way ANOVA test are used for the statistical analysis of the data.

Results and Discussion

It is found that during the year 2003-2004 of all the six elements analyzed, the highest concentration was recorded for Fe ($85.40 \pm 4.00 \mu\text{g/g}$), followed by Zn ($59.23 \pm 3.36 \mu\text{g/g}$), Mn ($10.33 \pm 0.68 \mu\text{g/g}$), Ni ($3.18 \pm 0.04 \mu\text{g/g}$), Co ($1.54 \pm 0.02 \mu\text{g/g}$) and Cu ($0.62 \pm 0.03 \mu\text{g/g}$) (Table: 2.1-2.6 & Fig: 2.1 and 2.2). The high concentration of Iron in relation to other elements might be due to the increase in leaching capacity from the surrounding areas in comparison to other elements. Other reason could be traced to the important of Fe and Zn in nutrition and growth of the fish, Fe is the most abundant transition elements, and probably the most well known metal in the biological systems (Forstner and Witthann, 1983). Due to lack of data on permissible limit of Fe in different fish samples, our data are comparing with the range of 65.9-2504 $\mu\text{g/g}$ Wet weight, observed by the study conducted by US Fish and Wildlife Services in 1993. It is found that our concentrations are in consistent with this range. It is also found that our results are in accordance with the study conducted by US Fish and Wildlife Services on the Colorado River, Arizona in the year 1988-1989 (Rompala *et al.*, 1984).

Mn concentrations are in accordance with the study conducted by US Fish and Wildlife Services in 1993 on the Colorado River, Arizona in the year 1988-1989. Ni concentrations are within the level of 3.75 $\mu\text{g/g}$ considered by the Panel on Nickel to be normal for aquatic organisms (Irwin, 1988). Co concentrations are in accordance with findings of Winger *et al.*, (1990), in a broad survey of contaminant levels in nine species of fish from eleven sites in the lower Savannah River, Georgia, and the Savannah National Wildlife Refuge, USA, where they reported mean cobalt levels of 0.1–2.5 $\mu\text{g/g}$

wet weight (Irwin, 1988). Zn and Cu are generally below the permissible limits of 1000 $\mu\text{g/g}$ and 30 $\mu\text{g/g}$ respectively as recommended by World Health Organization (WHO, 1987). It is also found that all the elements shows elevated concentration during summer season compare to the rest of the seasons. This may be attributed due to the increase leeching of elements from the surrounding area as a result of heavy rainfall during summer season, where the elements get concentrated in higher concentration in the water body which is then get accumulated in higher concentration in the body of fishes . The pattern of elemental concentration in fish sample is $\text{Fe} > \text{Zn} > \text{Mn} > \text{Ni} > \text{Co} > \text{Cu}$. Statistical analysis of the data shows that significant variation were observed, ($p < 0.05$). The distribution of elements in fishes showed that Fe constitutes the highest concentration while Cu recorded as the lowest concentration. The magnitude in the concentration of heavy metals in fishes compared to that in the water body confirmed that fish bioaccumulates these elements from the water body. In the year 2004-2005 of all the six elements analyzed, the highest concentration was recorded for Fe ($95.50 \pm 2.81 \mu\text{g/g}$), fallowed by Zn ($95.40 \pm 3.92 \mu\text{g/g}$), Mn ($8.44 \pm 0.62 \mu\text{g/g}$), Co ($0.97 \pm 0.03 \mu\text{g/g}$), Cu ($0.87 \pm 0.04 \mu\text{g/g}$) and Ni ($0.28 \pm 0.01 \mu\text{g/g}$), The pattern of elemental concentration is $\text{Fe} > \text{Zn} > \text{Mn} > \text{Co} > \text{Cu} > \text{Ni}$, Statistical analysis of the data shows significant variation, ($p < 0.05$) (Table: 2.7-2.12 & Fig: 2.3 and 2.4).

Concentrations of heavy metals in the body of fresh water fish varies considerably among different seasons, possibly due to differences in metal concentrations and chemical characteristics of water from which fish were sampled, ecological needs, metabolism and feeding pattern of the fishes and also the season in which the studies

were carried out. Studies have shown that fishes are able to accumulate and retain heavy metals from their environment and it has been shown that accumulations of metals in the body of fish is dependent upon exposure concentration and duration, as well as other factors such as alkalinity, temperature, hardness and metabolism of the fishes (Cusimano *et al.*, 1986; Heath, 1987).

The study shows that there is a variation in the concentrations of trace elements in whole body of this fishes. *Garra lamta* are usually consume by the local inhabitants of the area, fish samples are collected from Kynshi River over a period of two years and all the results are express in $\mu\text{g/g}$ wet weight. The variation in elements concentration may be due to many factors depending upon metabolic activities of the fishes, pH, Hardness, temperature, and alkalinity of the water bodies. Fish species are often top consumers in aquatic ecosystems (Dallinger *et al.*, 1987) and thus metal concentrations in fish can act as an environmental indicator of the state of the environment (Jorgenson and Pedersen, 1994).

There are two main pathways in which the heavy metals can enter the aquatic food chain, either directly through the digestive tract due to consumption of contaminated water or food, or non-dietary routes across permeable membranes such as gills (Handy, 1993; Ribeyre *et al.*, 1995; Farage *et al.*, 2000; Burger *et al.*, 2002). Sediments are well known to act as the most important reservoir or sink of metals and other pollutants in the aquatic environment (Van-Hattum *et al.*, 1993). Indirect exposure to contaminated sediments will take place when fish feed on benthic invertebrates that are ingesting

particulate matter. Direct exposure via the sediment can take place by release of contaminated particulate matter into the water column by both natural and anthropogenic disturbance which can result in metal remobilization (De Carvalho *et al.*, 1998).

The pollution of aquatic ecosystems by heavy metals is an important environmental problem (Rayms-Keller *et al.*, 1998), as heavy metals constitute some of the most hazardous substances that can bioaccumulate (Tarifeno-Silva *et al.*, 1982). Bioaccumulation is a process in which a chemical pollutant enters into the body of an organism and is not excreted, but rather collected in the organism's tissues (Zweig *et al.*, 1999). Metals that are deposited in the aquatic environment may accumulate in the food chain and cause ecological damage while also posing a threat to human health (Adams *et al.*, 1992). These health concerns are quite considerable. For example, cancer, damage to the nervous system has all been documented in humans as a result of metal consumption (Grimanis *et al.*, 1978).

Anthropogenic impacts including, industrial discharges, domestic sewage, non-point source runoff and atmospheric precipitation are the main sources of toxic heavy metals that enter aquatic systems (Hart, 1982; Langston *et al.*, 1999). However, metals also occur in small amounts naturally and enter aquatic systems through ore-bearing rocks, wind-blown dust, forest fires and vegetation (Tao *et al.*, 1999; Fernandez-Leborans & Herrero, 2000). Differences in the patterns of metals concentrations in fish species suggest either differences in which the fish species regulates metals or other factor that affect their exposure.

Conclusion

This study is to gather detailed information on the seasonal distribution of trace elements like Fe, Zn, Mn, Cu, Ni and Co in whole body of *Garra lamta* found in these aquatic ecosystems and the study period are of two years duration. All the results are express in wet weight basis. There is evidence that the use of fish alone to asses the level of pollution by heavy metals may be misleading if not carefully interpreted. However, the data obtain was not enough to jump into this conclusion. Therefore further work should be carried out to verify this conclusion. Furthermore, no attempt has been made in this study to investigate the relationship between the metals and age, sex and different organs of fish. Therefore more studies are needed in this respect to provide valid information for promoting fisheries research in this area.

Tables: (2.1-2.6): Seasonal variation of Fe, Zn, Mn, Cu Ni and Co in whole body of *Garra lamta* for the year 2003-2004

Table: 2.1. Seasonal variation of Fe with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(64.10-66.00)	(65.10 \pm 2.95 ^a)
Spring	(84.10-86.70)	(85.30 \pm 3.30 ^a)
Summer	(81.20-89.20)	(85.30 \pm 4.00 ^a)
Autumn	(37.20-45.30)	(41.43 \pm 4.10 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 148.8$). ^aMean \pm Standard Deviation, n=3

Table: 2.2. Seasonal variation of Zn with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(52.10-58.80)	(55.40 \pm 3.35 ^a)
Spring	(33.10-38.70)	(35.60 \pm 2.82 ^a)
Summer	(56.20-62.10)	(59.23 \pm 3.36 ^a)
Autumn	(28.50-34.20)	(31.40 \pm 2.85 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 63.85$). ^aMean \pm Standard Deviation, n=3

Table: 2.3. Seasonal variation of Mn with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(1.90-2.80)	(2.37 \pm 0.45 ^a)
Spring	(1.90-2.80)	(5.47 \pm 0.71 ^a)
Summer	(9.30-11.50)	(10.33 \pm 0.68 ^a)
Autumn	(7.80-9.10)	(8.40 \pm 0.65 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 33.85$). ^aMean \pm Standard Deviation, n=3

Table: 2.4. Seasonal variation of Cu with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(0.30-0.38)	(0.34 \pm 0.04 ^a)
Spring	(0.10-0.15)	(0.13 \pm 0.02 ^a)
Summer	(0.51-0.73)	(0.62 \pm 0.03 ^a)
Autumn	(0.48-0.52)	(0.50 \pm 0.02 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 36.92$). ^aMean \pm Standard Deviation, $n = 3$

Table: 2.5. Seasonal variation of Ni with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(2.93-2.97)	(2.95 \pm 0.02 ^a)
Spring	(2.51-2.58)	(2.54 \pm 0.03 ^a)
Summer	(3.14-3.21)	(3.18 \pm 0.04 ^a)
Autumn	(2.33-2.38)	(2.35 \pm 0.03 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 482.2$). ^aMean \pm Standard Deviation, $n = 3$

Table: 2.6. Seasonal variation of Co with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(1.33-1.38)	(1.36 \pm 0.02 ^a)
Spring	(1.22-1.27)	(1.25 \pm 0.03 ^a)
Summer	(1.52-1.57)	(1.54 \pm 0.02 ^a)
Autumn	(1.11-1.19)	(1.15 \pm 0.03 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 94.60$). ^aMean \pm Standard Deviation, $n = 3$

Tables: (2.7-2.12): Seasonal variation of Fe, Zn, Mn, Cu Ni and Co in whole body of *Garra lamta* for the year 2004-2005

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(47.00-50.10)	49.23 \pm 1.33 ^a)
Spring	(64.90-67.50)	66.40 \pm 1.35 ^a)
Summer	(92.60-98.20)	95.50 \pm 2.81 ^a)
Autumn	(27.50-31.30)	29.40 \pm 1.90 ^a)

Table: 2. 7. Seasonal variation of Fe with range, mean and Standard Deviation.

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 624.3$).^aMean \pm Standard Deviation, $n=3$

Table: 2. 8. Seasonal variation of Zn with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(88.50-96.20)	(92.50 \pm 3.86 ^a)
Spring	(73.80-84.20)	(79.56 \pm 5.29 ^a)
Summer	(94.30-96.40)	(95.40 \pm 3.92 ^a)
Autumn	(64.30-69.20)	(67.00 \pm 2.49 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 40.64$).^aMean \pm Standard Deviation, $n=3$

Table: 2.9. Seasonal variation of Mn with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(2.52-2.72)	(2.62 \pm 0.10 ^a)
Spring	(6.82-8.58)	(7.70 \pm 0.52 ^a)
Summer	(7.55-9.20)	(8.44 \pm 0.62 ^a)
Autumn	(6.90-8.00)	(7.60 \pm 0.61 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 46.40$).^aMean \pm Standard Deviation, $n=3$

Table: 2.10. Seasonal variation of Cu with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(0.27-0.30)	(0.28 \pm 0.03 ^a)
Spring	(0.77-0.89)	(0.83 \pm 0.06 ^a)
Summer	(0.85-0.89)	(0.87 \pm 0.04 ^a)
Autumn	(0.62-0.68)	(0.65 \pm 0.03 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 139.8$). ^aMean \pm Standard Deviation, $n = 3$

Table: 2.11. Seasonal variation of Ni with range, mean and Standard Deviation.

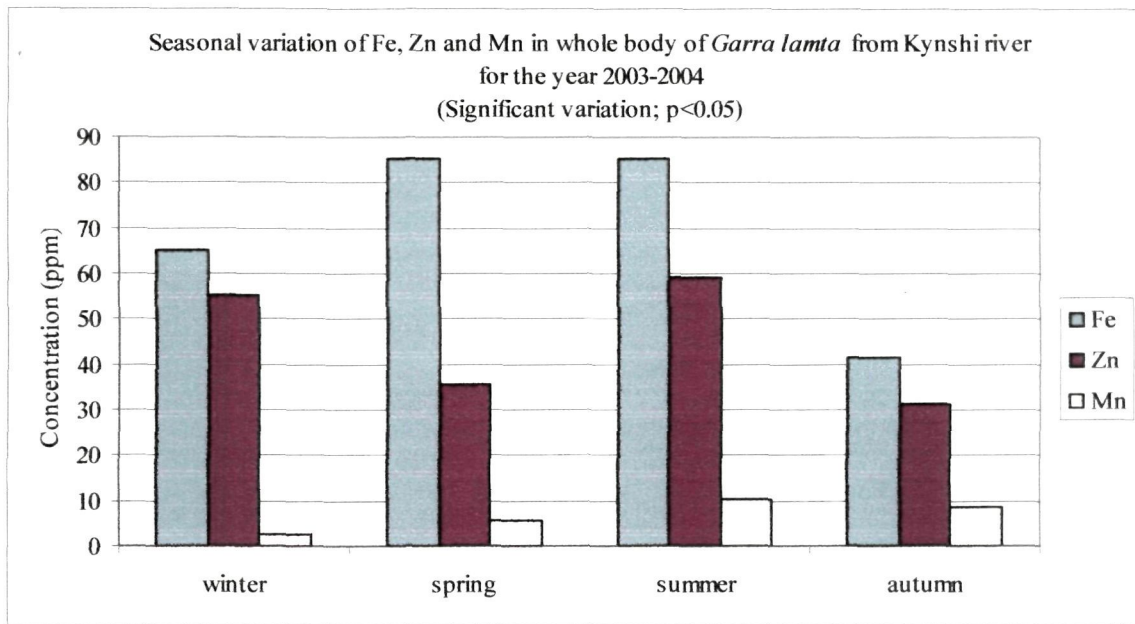
Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(0.22-0.28)	(0.25 \pm 0.03 ^a)
Spring	(0.18-0.22)	(0.20 \pm 0.02 ^a)
Summer	(0.27-0.29)	(0.28 \pm 0.01 ^a)
Autumn	(0.20-0.24)	(0.22 \pm 0.02 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 8.291$). ^aMean \pm Standard Deviation, $n = 3$

Table: 2.12. Seasonal variation of Co with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(0.75-0.77)	(0.76 \pm 0.01 ^a)
Spring	(0.78-0.82)	(0.80 \pm 0.02 ^a)
Summer	(0.96-0.98)	(0.97 \pm 0.03 ^a)
Autumn	(0.87-0.91)	(0.89 \pm 0.02 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 106.0$). ^aMean \pm Standard Deviation, $n = 3$



Figures: 2.1: Seasonal variation of Fe, Zn and Mn in whole body of *Garra lamta* for the year 2003-2004

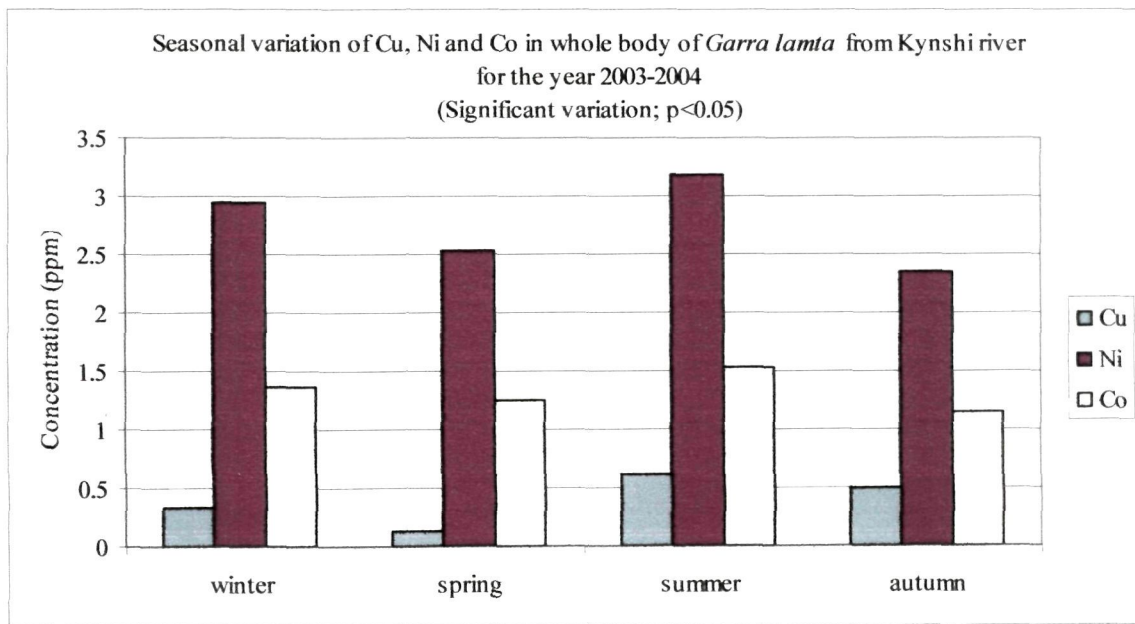


Figure: 2.2: Seasonal variation of Cu, Ni and Co in whole body of *Garra lamta* for the year 2003-2004

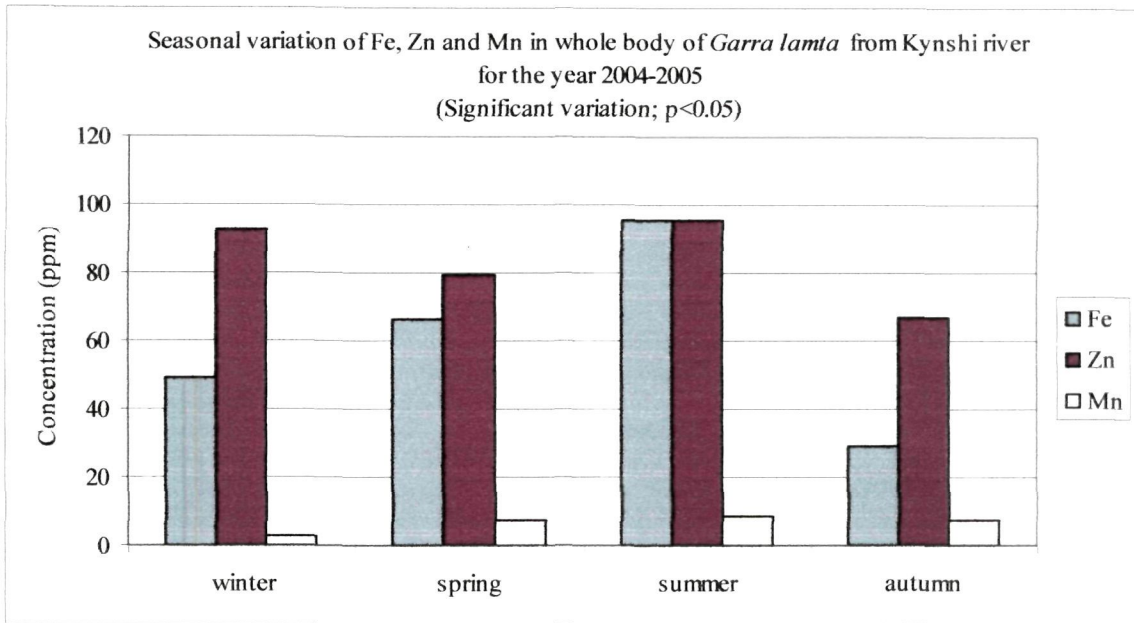


Figure: 2.3: Seasonal variation of Fe, Zn and Mn in whole body of *Garra lamta* for the year 2004-2005

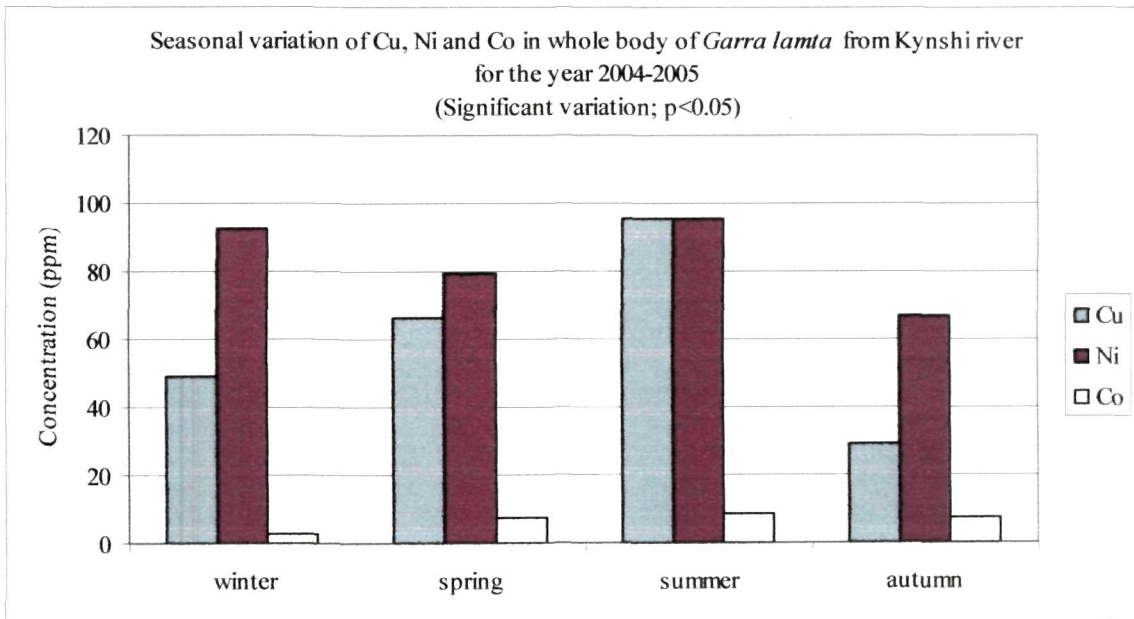


Figure: 2.4: Seasonal variation of Cu, Ni and Co in whole body of *Garra lamta* for the year 2004-2005

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Chapter-III

(Seasonal variation of trace elements in water samples from Kynshi River)

Introduction

Heavy metals enter the aquatic environment naturally through weathering of the Earth's crust. In addition to geological weathering, human activities have also introduced large quantities of metals to the aquatic environment, in some cases upsetting the natural steady state balance (Forstner and Wittmann, 1983).

Over the several decades, increasing use of metals in industry has lead to serious environmental pollution through effluents and emanation (Phillips, 1990). Under certain environmental condition, heavy metals may accumulate to a toxic concentration (Guyen *et al.*, 1999), and cause ecological damage (Harms, 1975; Jefferies and Freestone, 1984; Freedman, 1989). In general, studies on heavy metals can be important in two main aspects. First from the public health point of view, where the attention has been drawn to the necessity of measuring the accumulation of heavy metals. Second from the aquatic environment view point, the main problem has been to prevent biological deterioration and to identify the sources which threaten ecological equilibrium. In this regard, the more abundant metals such as copper, zinc and manganese may sometimes represent grater hazard than lead, mercury and cadmium (Kinne, 1984).

Aquatic systems are very sensitive to heavy metal pollutants and gradual increase in the levels of such metals in aquatic environment, mainly due to anthropogenic sources, became a problem of primary concern (Aliot and Frenet, 1990; Elnemr, 2003;

Hadjmohammad, 1988). This is due to persistence as they are not usually eliminated either by biodegradation or by chemical means, in contrast to most organic pollutants. Moreover, the decay of organic materials in aquatic systems together with detritus formed by natural weathering processes provides a rich source of nutrients in both the bottom sediments and overlying water body. Microorganisms, microflora and algae are capable of incorporating and accumulating metal species into their living cells from various supply sources. Consequently, small fish become enriched with the accumulated substances. Predatory fish again, general display higher levels than their prey. Eventually man, consuming the fish, inevitably suffers from the results of an enrichment taken place at each trophic level, where less is extracted than ingested (Forstner and Wittmann, 1983; Haug *et al.*, 1974; Kalay and Aya., 1999; Kargin and Erdem, 1991; Khan *et al.*, 1989).

Materials and methods

Water samples were collected using acid washed polyethylene plastic containers with screw caps and amber glass bottles. Washing procedures for containers were as recommended in standard methods for waters and wastewaters (APHA, 1992). For general parameters determination, 1 litre High Density Polyethylene (HDPE) bottles were thoroughly washed with de-ionized water, and rinsed many times with Milli-Q water and finally soaked in 50% nitric acid for 24 hr before final rinse with Milli-Q water. 150ml of water samples collected from the selected sites are taken and evaporate approximately to 40ml. 3ml of conc. HNO₃ electronic grade are added and evaporate nearly to dryness. 10ml of 0.25% HNO₃ are added and filter through 542 Whatman filter paper, the residue

are wash with another 10ml of 0.25 HNO₃ and the total volume are made up to 25ml by the addition 0.25 HNO₃. The extract was analyzed using Atomic Absorption Spectrophotometer (AAS) at Environmental Assessment Division, (EAD), Bhabha Atomic Research Centre, (BARC), Mumbai.

Results and discussion

Elemental analysis of water samples from Kynshi River shows that there is a seasonal fluctuation in the concentration of trace elements in this aquatic ecosystem. This variation may be due to many factors such as pH, hardness, temperature, and alkalinity of the water bodies. During the year 2003-2004 highest concentration was recorded for Fe ($75.34 \pm 1.53 \mu\text{g/l}$), followed by Ni ($27.55 \pm 0.55 \mu\text{g/l}$), Mn ($26.00 \pm 0.80 \mu\text{g/l}$), Co ($13.58 \pm 0.47 \mu\text{g/l}$), Zn ($13.17 \pm 0.58 \mu\text{g/l}$) and Cu ($1.82 \pm 0.17 \mu\text{g/l}$) (Table: 3.1-2.6 & Fig: 2.1 and 2.2). Statistical analysis of the data shows that significant variation were observed, ($p < 0.05$). The pattern of elemental concentration in water sample is Fe > Ni > Mn > Co > Zn > Cu. The distribution of elements in this aquatic ecosystem showed that Fe constitutes the highest concentration while Cu exhibit lowest concentrations. It is also found that all the elements shows elevated concentration during summer season compare to the rest of the seasons. This may be because of the increase leaching of elements from the surrounding area as a result of heavy rainfall during summer season, where the elements get concentrated in higher concentration in the water body.

In the year 2004-2005 Fe exhibit elevated concentration of ($44.72 \pm 1.03 \mu\text{g/l}$), followed by Mn ($25.52 \pm 1.40 \mu\text{g/l}$), Zn ($17.86 \pm 0.75 \mu\text{g/l}$), Co ($13.29 \pm 0.78 \mu\text{g/l}$), Ni

($4.26 \pm 0.06 \mu\text{g/l}$) and Cu ($2.45 \pm 0.22 \mu\text{g/l}$) (Table: 3.7-3.12 & Fig: 3.3 and 3.4). Significant variation were observed, ($p < 0.05$). The pattern of elemental concentration in water sample is $\text{Fe} > \text{Mn} > \text{Zn} > \text{Co Ni} > \text{Cu}$. Study of trace elemental concentration in water samples of Kynshi river it is found that over a period of two years Fe concentrations have minimum concentrations of $16.20 \mu\text{g/l}$ during winter season in the year 2004, and maximum concentration of $75.34 \mu\text{g/l}$ during summer season of the year 2004. These concentrations are found to be below the permissible limit of 20 ppm as prescribe by USEPA. WHO does not set any limit for Iron in water samples because Iron is not of health concern at concentrations normally observed in drinking water. Zn show low concentration of $3.77 \mu\text{g/l}$ during spring season in the year 2004, and maximum concentration of $17.86 \mu\text{g/l}$ during summer season of the year 2005 and it falls well below the permissible limit of 1 ppm as prescribed by USEPA. WHO does not set any limit for Zinc in water samples because Zn is not of health concern at concentrations normally observed in drinking water.

Mn exhibit highest concentration of $26.00 \mu\text{g/l}$ during summer season of the year 2004, and it is well below the permissible limit of 0.4 ppm as prescribe by WHO. Highest Cu concentration is $2.45 \mu\text{g/l}$ during summer season of the year 2005 and its concentration is below the permissible limit of 2 ppm as prescribe by WHO. Ni concentrations shows maximum concentration of $27.55 \mu\text{g/l}$ during summer season of the year 2004 and its concentration are found below the permissible limit of $70 \mu\text{g/l}$ as prescribe by WHO. Co concentrations are below the permissible limit of 100 ppb as prescribe by WHO.

The presence of metal pollutants in freshwater is known to disturb the balance of aquatic ecosystem and this has been noticed to manifest in the presence of some irregularities in fish physiology as fishes tend to concentrate some metals in their body tissues (Kakulu, and Osibanjo, 1986). It was also recognized that the increased environmental burdens of metals and acids in rivers were potentially stressful to fishes. For instance, fish population may be lost from rivers, apparently because of reproduction failures. Hervey and Lee, (1982) stressed the significance of the increased metal loadings that have been coincidental with acidification and concluded that the reproductive failure is a symptom of both acids and metal stresses. Fishes are sensitive indicators of heavy metals pollution (Adeyemi *et al.*, 1996).

Conclusion

It is found that the concentrations of all the selected elements are within the acceptable standards of WHO guidelines, and therefore at these concentrations the elements would not pose any serious threat to the life of biota or man as a consumer. Guideline values are derived for many chemical constituents of drinking-water. A guideline value normally represents the concentration of a constituent that does not result in any significant risk to health over a lifetime of consumption. A number of provisional guideline values have been established at concentrations that are reasonably achievable through practical treatment approaches or in analytical laboratories, in these cases, the guideline value is above the concentration that would normally represent the calculated health-based value. Guideline values are also designated as provisional when there is a high degree of uncertainty in the toxicology and health data.

Tables: (3.1-3.6): Seasonal variation of Fe, Zn, Mn, Cu Ni and Co from Kynshi River for the year 2003-2004

Table: 3.1. Seasonal variation of Fe (Dec' 2003 – Nov' 2004) with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/l}$)	Mean \pm SD
Winter	(15.65-17.55)	(16.20 \pm 1.45 ^a)
Spring	(30.55-32.41)	(31.50 \pm 0.96 ^a)
Summer	(73.67-76.73)	(75.34 \pm 1.53 ^a)
Autumn	(49.50-50.50)	(50.33 \pm 1.04 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 153$). ^aMean \pm Standard Deviation, $n = 3$

Table: 3.2. Seasonal variation of Zn with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/l}$)	Mean \pm SD
Winter	(6.75-8.85)	(8.13 \pm 0.62 ^a)
Spring	(3.50-4.00)	(3.77 \pm 0.25 ^a)
Summer	(12.50-13.55)	(13.17 \pm 0.58 ^a)
Autumn	(6.01-6.85)	(6.56 \pm 0.48 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 106.0$). ^aMean \pm Standard Deviation, $n = 3$

Table: 3.3. Seasonal variation of Mn with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/l}$)	Mean \pm SD
Winter	(15.22-15.95)	(15.57 \pm 0.37 ^a)
Spring	(12.14-13.02)	(12.57 \pm 0.44 ^a)
Summer	(25.11-26.67)	(26.00 \pm 0.80 ^a)
Autumn	(17.18-18.22)	(17.65 \pm 0.53 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 318.0$). ^aMean \pm Standard Deviation, $n = 3$

Table: 3.4. Seasonal variation of Cu with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/l}$)	Mean \pm SD
Winter	(1.32-1.55)	(1.43 \pm 0.11 ^a)
Spring	(0.95-1.15)	(1.04 \pm 0.10 ^a)
Summer	(1.65-1.98)	(1.82 \pm 0.17 ^a)
Autumn	(1.24-1.28)	(1.26 \pm 0.02 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 6.701$). ^aMean \pm Standard Deviation, $n = 3$

Table: 3.5. Seasonal variation of Ni with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/l}$)	Mean \pm SD
Winter	(22.15-23.12)	(22.59 \pm 0.49 ^a)
Spring	(18.11-19.15)	(18.60 \pm 0.52 ^a)
Summer	(26.56-28.21)	(27.55 \pm 0.87 ^a)
Autumn	(21.12-22.14)	(21.71 \pm 0.53 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 106.4$). ^aMean \pm Standard Deviation, $n = 3$

Table: 3.6. Seasonal variation of Co with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/l}$)	Mean \pm SD
Winter	(6.02-6.98)	(6.48 \pm 0.48 ^a)
Spring	(8.11-9.12)	(8.61 \pm 0.51 ^a)
Summer	(13.12-14.06)	(13.58 \pm 0.47 ^a)
Autumn	(7.03-8.12)	(7.56 \pm 0.55 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 117.5$). ^aMean \pm Standard Deviation, $n = 3$

Tables: (3.7-3.12): Seasonal variation of Fe, Zn, Mn, Cu Ni and Co from Kynshi River for the year 2004-2005

Table: 3.7. Seasonal variation of Fe with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/l}$)	Mean \pm SD
Winter	(22.14-23.25)	(22.63 \pm 0.57 ^a)
Spring	(15.5-19.22)	(17.24 \pm 2.12 ^a)
Summer	(44.12-45.91)	(44.72 \pm 1.03 ^a)
Autumn	(24.90-26.60)	(25.60 \pm 0.89 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 302.4$). ^aMean \pm Standard Deviation, $n=3$

Table: 3.8. Seasonal variation of Zn with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/l}$)	Mean \pm SD
Winter	(13.35-14.60)	(13.82 \pm 0.68 ^a)
Spring	(13.33-14.60)	(13.94 \pm 0.64 ^a)
Summer	(17.34-18.72)	(17.86 \pm 0.75 ^a)
Autumn	(7.30-8.50)	(8.17 \pm 0.76 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 95.16$). ^aMean \pm Standard Deviation, $n=3$

Table: 3.9. Seasonal variation of Mn with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/l}$)	Mean \pm SD
Winter	(13.94-15.31)	(14.56 \pm 0.69 ^a)
Spring	(15.50-16.90)	(16.37 \pm 0.76 ^a)
Summer	(25.12-26.92)	(25.52 \pm 1.40 ^a)
Autumn	(12.13-13.12)	(12.72 \pm 0.52 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 184.2$). ^aMean±Standard Deviation, n=3

Table: 3.10. Seasonal variation of Cu with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/l}$)	Mean±SD
Winter	(0.36-0.42)	(0.39±0.03 ^a)
Spring	(1.37-1.43)	(1.40±0.03 ^a)
Summer	(2.38-2.79)	(2.45±0.22 ^a)
Autumn	(1.52-1.56)	(1.54±0.02 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 185.0$). ^aMean±Standard Deviation, n=3

Table: 3.11. Seasonal variation of Ni with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/l}$)	Mean±SD
Winter	(2.51-2.98)	(2.73±0.20 ^a)
Spring	(3.12-3.54)	(3.26±0.23 ^a)
Summer	(4.21-4.32)	(4.26±0.06 ^a)
Autumn	(3.12-3.25)	(3.17±0.07 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 41.24$). ^aMean±Standard Deviation, n=3

Table: 3.12. Seasonal variation of Co with range, mean and Standard Deviation.

Seasons	Range ($\mu\text{g/l}$)	Mean±SD
Winter	(7.13-8.54)	(7.77±0.71 ^a)
Spring	(8.58-10.11)	(9.37±0.77 ^a)
Summer	(12.44-13.98)	(13.29±0.78 ^a)
Autumn	(11.12-11.89)	(11.19±0.68 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 31.47$). ^aMean±Standard Deviation, n=3

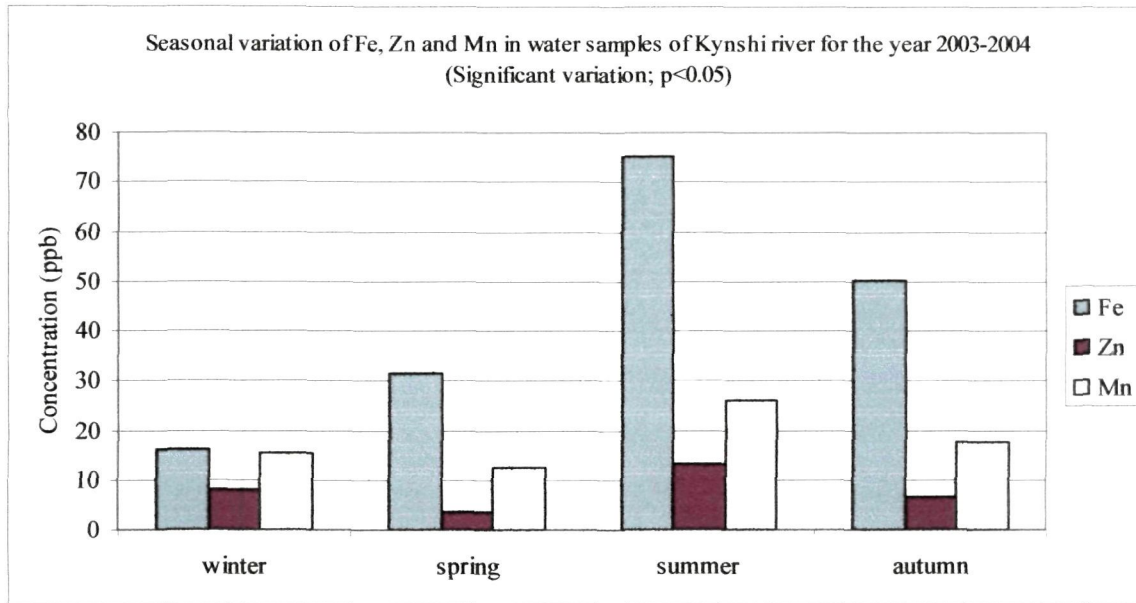


Figure: 3.1. Seasonal variations of Fe, Zn and Mn in water samples of Kynshi River (2003-2004)

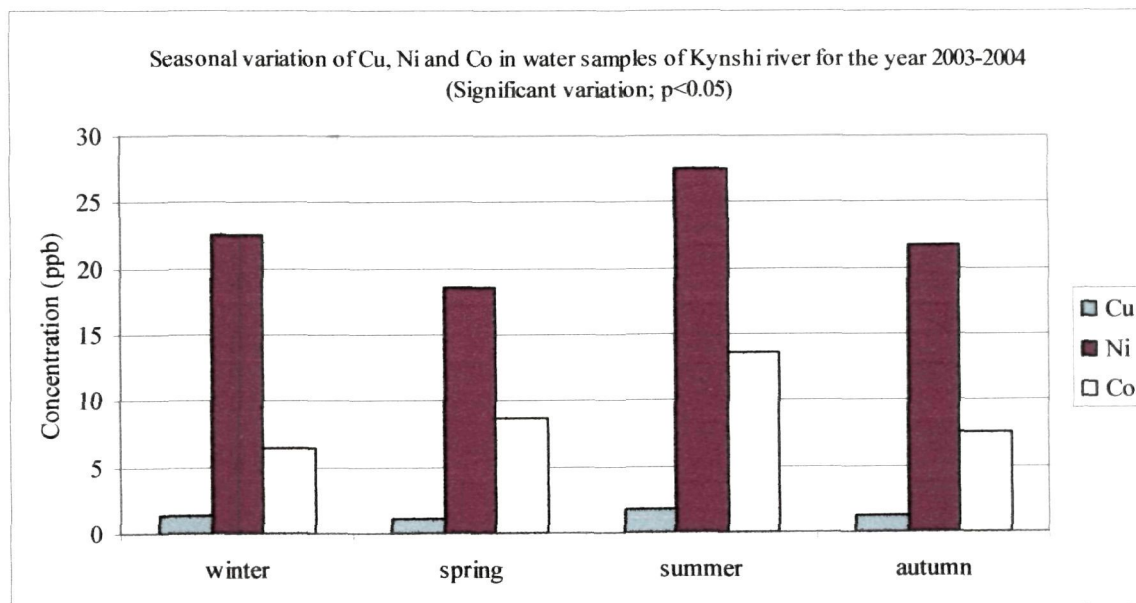


Figure: 3.2. Seasonal variations of Cu, Ni and Co in water samples of Kynshi River (2003-2004)

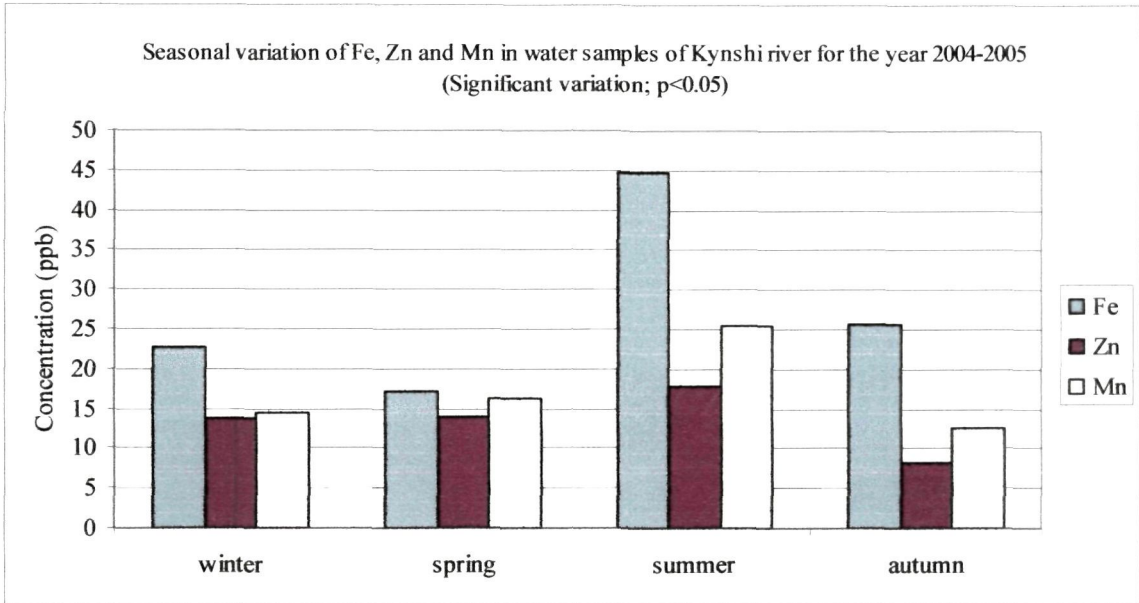


Figure: 3.3. Seasonal variations of Fe, Zn and Mn in water samples of Kynshi River (2004-2005)

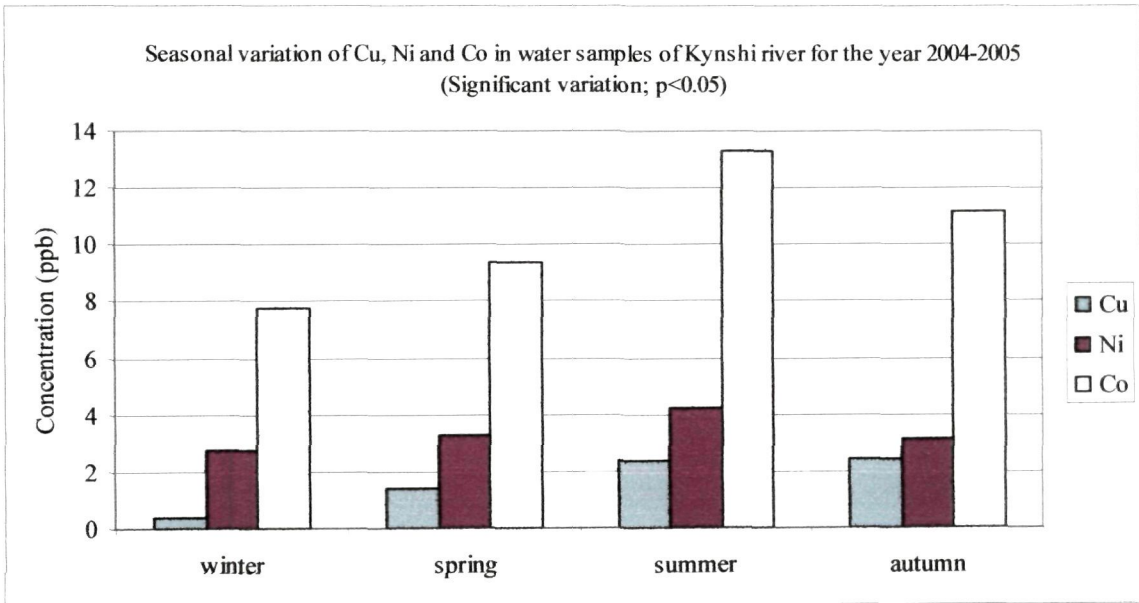


Figure: 3.4. Seasonal variations of Cu, Ni and Co in water samples of Kynshi River (2004-2005)

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Chapter-IV
(Elemental Correlation study in Garra lamta between Kynshi and Rilang Rivers)

Introduction

Correlation is one of the most common and most useful statistics. A correlation is a single number that describes the degree of relationship between two variables. In our study correlation in the concentration of the selected elements in whole body of *Garra lamta* between the two rivers are perform, and it show significant positive correlation at different level of significant. In this study Pearson's Correlation Coefficient (r), are used. In correlation study it's emphasis is on the degree to which a linear model may describe the relationship between two variables (two rivers: Kynshi and Rilang River).

Quite often in environmental analysis we may want to investigate whether there is a significant relationship between two variables (x and y). For example, we may want to compare the results of two different methods over a range of analyte concentrations in order to assess their suitability for a particular analysis, or we may want to compare the concentration of analytes of two different areas or sites (Rodgers and Nicewander, 1988; Gayen, 1951; Francis, 1973; Edwards, 1976). Normally we would plot x against y and visually ascertain whether a relationship exists. However, it is not uncommon to find considerable scatter when plotting the results of environmental analysis in this way owing to the complex nature of the samples and environmental processes that influence the concentrations of substances in different samples. Such graphs are called *scatterplots*. We therefore have to rely on statistics to tell us whether a significant relationship exists between different variables. Regression lines are drawn only for those plots where the

value of the correlation coefficient indicates a significant relationship (Gonick and Smith, 1993; Kenney and Keeping, 1962; Press *et al.*, 1992; Snedecor and Cochran, 1980; Spiegel, 1992).

Materials and methods

Pearson's correlation coefficient can be calculated manually from the following equation:

$$r = \frac{n \sum xy - (\sum x) (\sum y)}{\{[n \sum x^2 - (\sum x)^2] [n \sum y^2 - (\sum y)^2]\}^{1/2}}$$

Where:

- n = Number of pairs of scores
- $\sum xy$ = Sum of the products of paired scores
- $\sum x$ = Sum of x scores
- $\sum y$ = Sum of y scores
- $\sum x^2$ = Sum of squared of x scores
- $\sum y^2$ = Sum of squared of y scores

The process is tedious. Most scientific calculators are programmed to calculate the correlation coefficient. A correlation table is used to evaluate the level of significance of a linear relationship between x and y. The table gives critical value of r for different numbers of data pairs (n). Critical value of r are usually taken at p=0.05. If the calculated value of r is greater than that of critical value given in the table, then in all likelihood there is a significant linear relationship between x and y, i.e. there is less than 5% probability (1 in 20) that this could be due to random data points. If r is lower than the

critical value, then there is no significant linear relationship between x and y. It should be remembered that correlation coefficient is a valid indicator of association between two variables (Whittaker and Robinson, 1967; Kenney and Keeping, 1962). The data obtained from Kynshi and Rilang rivers are used for correlation study.

Results and discussion

Correlation studies of Fe, Zn, Mn, Cu, Ni and Co in whole body tissue of the fish samples (*Garra lamta*) between the two rivers (Kynshi and Rilang) were carried out. Correlation study of all the selected elements for the year 2003-2004 are depicted in fig: 4.1 & 2; 4.3 & 4; 4.5 & 6; 4.7 & 8; 4.9 & 10; 4.11 & 12. It is found that Fe and Zn shows high positive correlation between the two rivers ($p < 0.10$) where r value for Fe and Zn are 0.93. Mn exhibit high positive correlation ($p < 0.05$; $r = 0.96$). At ($p < 0.05$) confidence level Cu and Co shows strong positive correlation where the r value for Cu and Co are 0.97 and 0.99 respectively. Ni also exhibit positive correlation ($p < 0.10$; $r = 0.82$). Correlation is one of the most common and most useful statistics. In our study correlation in the concentration of the selected elements in whole body of *Garra lamta* between the two rivers are performed and it shows significant positive correlation at different levels of significance ($p < 0.10$ and $P < 0.05$). In this study Pearson Correlation Coefficient (r), are used. During the year 2004-2005 Correlation studies of Fe, Zn, Mn, Cu, Ni and Co in whole body tissue of the fish samples shows strong positive correlation between the two sites. Correlation study of all the selected elements for the year 2004-2005 are depicted in fig: 4.13 & 14; 4.15 & 16; 4.17 & 18; 4.19 & 20; 4.21 & 22; 4.23 & 24. Fe, Zn, Mn, Cu and Ni shows high positive correlation between the two rivers ($p < 0.10$), where r value for

Fe, Zn, Mn, Cu and Ni are 0.93; 0.92; 0.94; 0.94 and 0.80 respectively. Co exhibit high positive correlation ($p < 0.05$; $r = 0.98$).

Correlation studies of trace elements in water samples of the two rivers are also carried out for the year 2003-2004 and 2004-2005. Correlation study of all the selected elements for the year 2003-2004 are depicted in fig: 4.25 & 26; 4.27 & 28; 4.29 & 30; 4.31 & 32; 4.33 & 34; 4.35 & 36. Fe, Mn, Cu, Ni and Co shows high positive correlation between the two rivers ($p < 0.05$), where 'r' value for Fe, Mn, Cu, Ni and Co are 0.97; 0.96; 0.95; 0.98 and 0.98 respectively. Zn exhibit high positive correlation ($p < 0.01$; $r = 0.86$). Correlation study of all the selected elements for the year 2004-2005 are depicted in fig: 4.37 & 38; 4.39 & 40; 4.41 & 42; 4.43 & 44; 4.45 & 46; 5.47 & 48. Fe, Mn, Cu, and Co shows high positive correlation between the two rivers ($p < 0.05$), where 'r' value for Fe, Mn, Cu and Co are 0.96; 0.97; 0.97 and 0.98 respectively. Zn and Ni exhibit significant correlation ($p < 0.01$) where r value for Zn and Ni are 0.93 and 0.89 respectively.

The strong positive correlation observed between the two rivers may be due to similarities in the geological composition of both the study sites, and also due to the similarities in the rainfall distribution of the area. The southern parts of the plateau of Meghalaya receive the heaviest rainfall, which is due to its location at the head of Bangladesh plains. The south west monsoon strikes these margins as it rises abruptly from the plains. The vertical movement of this moist monsoon streams precipitate heavily in the region, which lead to the influx of trace elements into the water bodies and finally taken up by the fishes and accumulate in higher concentration during summer season than

the rest of the seasons. The correlation r are used to test the significant linear relationship between the two study sites , values of 'r' can vary between -1 and 1, values of 1 or -1 indicates a perfect relationship between the two sites. In this study we observed a strong positive correlation at different level of significant. The chemical and geochemical properties of elements are also important inherent characteristics that affect the relations of these elements between the two study sites.

Conclusion

In this study we observed a highly positive correlation between the two study sites. New analytical techniques have enhanced current understanding of the behavior of trace and ultra trace elements in the biogeochemical cycling, chemical speciation, bioavailability and bioaccumulation. The significance level calculated for each correlation is a primary source of information about the reliability of the correlation. As explained before, the significance of a correlation coefficient of a particular magnitude will change depending on the size of the sample from which it was computed. The test of significance is based on the assumption that the distribution of the residual values (i.e., the deviations from the regression line) for the dependent variable y follows the normal distribution.

**Correlation study in the Seasonal variation of selected elements in *Garra lamta* between the two rivers with Range, mean and Standard Deviation.

(December 2003 – November 2004).

Table: 4.1. Correlation study of Fe

Seasons	Range ($\mu\text{g/g}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(64.10-66.00)	(56.20-60.26)	(65.10 \pm 2.95 ^a)	(58.23 \pm 2.03 ^a)
Spring	(72.10-78.70)	(61.45-65.55)	(85.43 \pm 3.30 ^a)	(63.50 \pm 2.05 ^a)
Summer	(84.10-86.70)	(78.20-80.22)	(85.30 \pm 4.00 ^a)	(79.21 \pm 1.01 ^a)
Autumn	(37.20-45.30)	(33.35-37.45)	(41.43 \pm 4.10 ^a)	(35.40 \pm 2.05 ^a)

Significant Correlation, ($p < 0.10$; $r = 0.93$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.2. Correlation study of Zn

Seasons	Range ($\mu\text{g/g}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(52.10-58.80)	(46.20-50.22)	(55.40 \pm 3.35 ^a)	(48.21 \pm 2.01 ^a)
Spring	(33.10-38.70)	(37.25-41.29)	(35.60 \pm 2.82 ^a)	(39.27 \pm 2.02 ^a)
Summer	(56.20-62.10)	(61.21-63.23)	(59.23 \pm 3.36 ^a)	(62.22 \pm 1.05 ^a)
Autumn	(28.50-34.20)	(26.18-30.22)	(31.40 \pm 2.85 ^a)	(28.20 \pm 2.02 ^a)

Significant Correlation, ($p < 0.10$; $r = 0.93$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.3. Correlation study of Manganese Mn

Seasons	Range ($\mu\text{g/g}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(1.90-2.80)	(3.48-3.56)	(2.37 \pm 0.45 ^a)	(3.52 \pm 0.04 ^a)
Spring	(4.70-6.10)	(4.47-4.55)	(5.47 \pm 0.71 ^a)	(4.51 \pm 0.04 ^a)
Summer	(9.30-11.50)	(13.20-13.30)	(10.33 \pm 0.68 ^a)	(13.25 \pm 0.05 ^a)
Autumn	(7.80-9.10)	(11.16-11.26)	(8.40 \pm 0.65 ^a)	(11.21 \pm 0.05 ^a)

Significant Correlation, ($p < 0.05$; $r = 0.96$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.4. Correlation study of Cu

Seasons	Range ($\mu\text{g/g}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(0.30-0.38)	(0.37-0.41)	(0.34 \pm 0.04 ^b)	(0.39 \pm 0.02 ^a)
Spring	(0.10-0.15)	(0.25-0.31)	(0.13 \pm 0.02 ^b)	(0.28 \pm 0.03 ^a)
Summer	(0.51-0.73)	(0.74-0.82)	(0.62 \pm 0.03 ^b)	(0.78 \pm 0.04 ^a)
Autumn	(0.48-0.52)	(0.56-0.63)	(0.50 \pm 0.02 ^b)	(0.59 \pm 0.03 ^a)

Significant Correlation, ($p < 0.05$; $r = 0.97$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.5. Correlation study of Ni

Seasons	Range ($\mu\text{g/g}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(0.38-0.42)	(1.64-1.72)	(2.95 \pm 0.02 ^b)	(1.68 \pm 0.04 ^a)
Spring	(0.67-0.70)	(1.54-1.60)	(2.54 \pm 0.03 ^b)	(1.57 \pm 0.03 ^a)
Summer	(0.75-0.91)	(3.70-3.80)	(3.18 \pm 0.04 ^b)	(3.75 \pm 0.05 ^b)
Autumn	(0.47-0.53)	(1.29-1.35)	(2.35 \pm 0.03 ^b)	(1.32 \pm 0.03 ^a)

Significant Correlation, ($p < 0.10$; $r = 0.82$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.6. Correlation study of Co

Seasons	Range ($\mu\text{g/g}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(0.48-0.52)	(1.26-1.36)	(1.36 \pm 0.02 ^b)	(1.31 \pm 0.05 ^b)
Spring	(0.51-0.75)	(1.15-1.21)	(1.25 \pm 0.03 ^b)	(1.18 \pm 0.03 ^b)
Summer	(0.61-0.80)	(1.56-1.64)	(1.54 \pm 0.02 ^b)	(1.60 \pm 0.04 ^b)
Autumn	(0.07-0.14)	(1.46-1.50)	(1.45 \pm 0.03 ^b)	(1.48 \pm 0.02 ^b)

Significant Correlation, ($p < 0.05$; $r = 0.99$). ^aMean \pm Standard Deviation, $n = 3$

**Correlation study of selected elements in *Garra lamta* between the two rivers (December 2003 – November 2004).

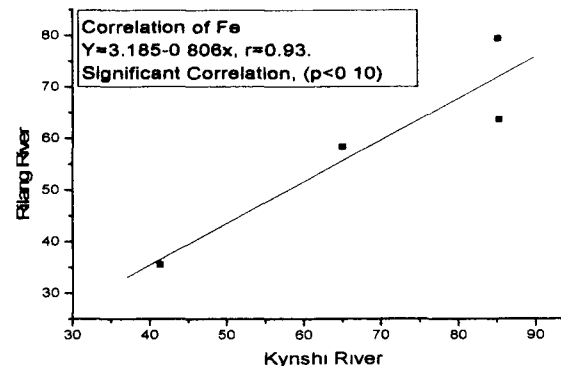
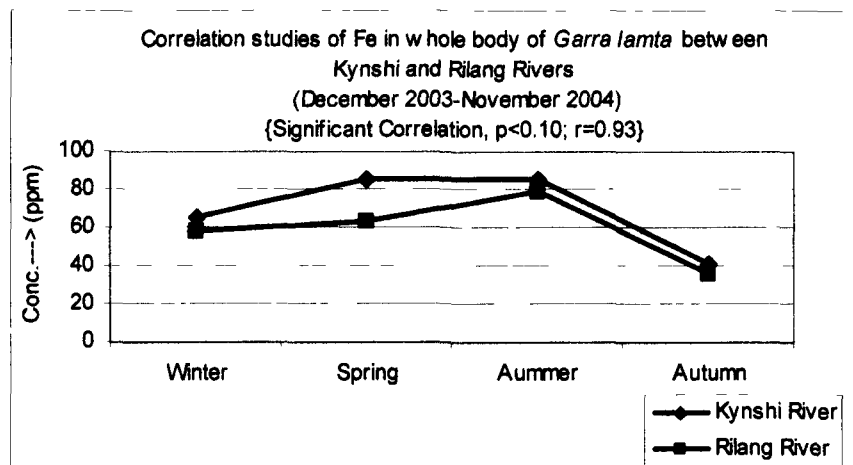


Figure: 4.1 & 4.2. Correlation study of Fe

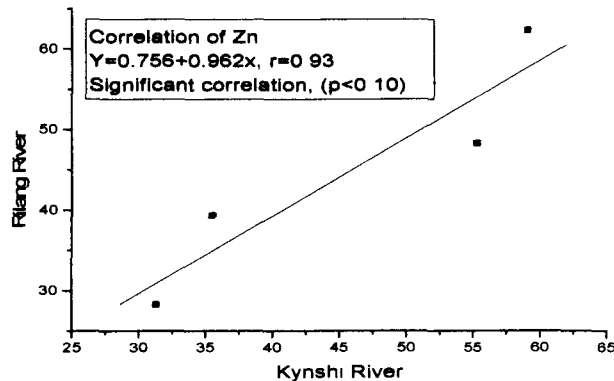
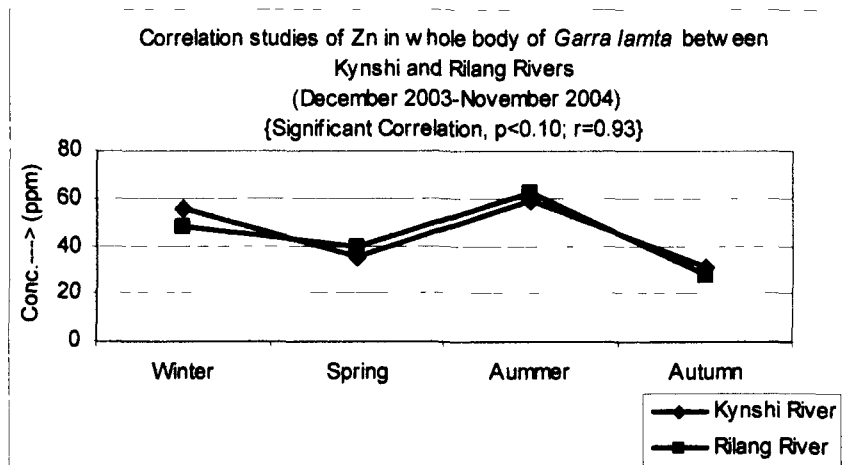


Fig: 4.3 & 4.4. Correlation study of Zn

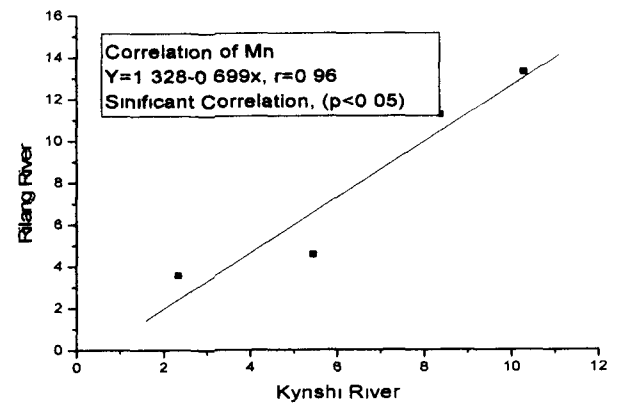
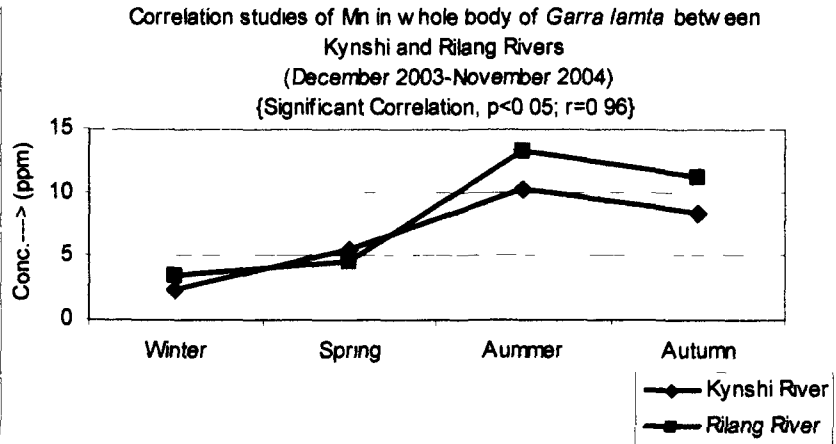


Fig: 4.5 & 4.6. Correlation study of Mn

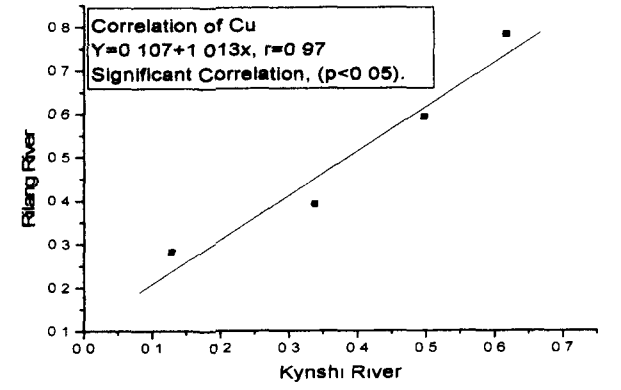
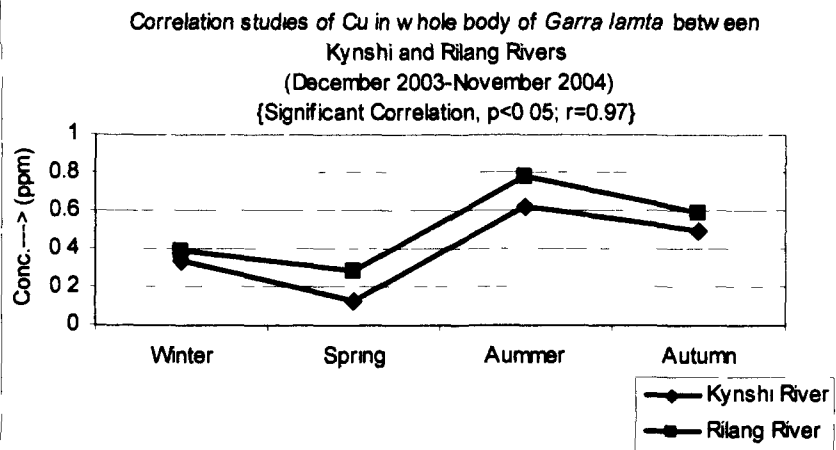


Fig: 4.7 & 4.8. Correlation study of Cu

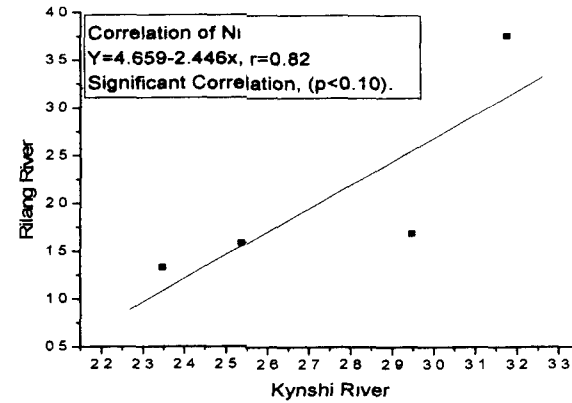
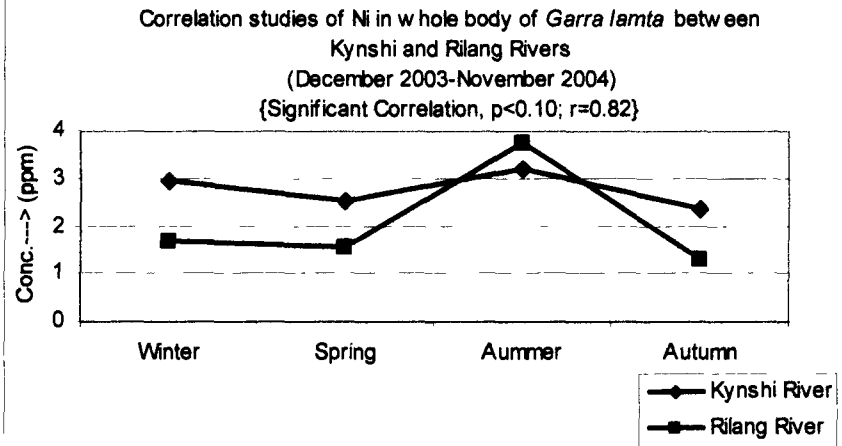


Fig: 4.9 & 4.10. Correlation study of Ni

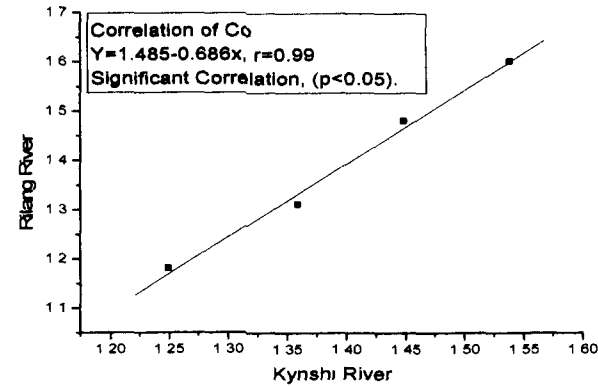
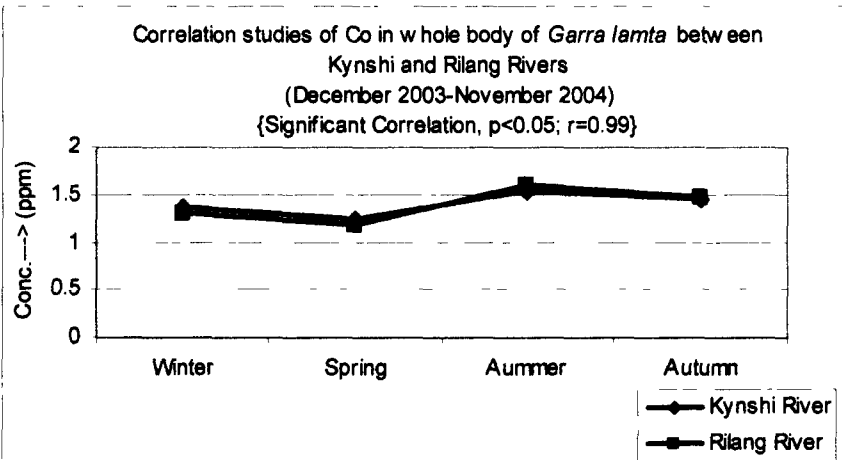


Fig: 4.11 & 4.12. Correlation study of Co

**Correlation study in the Seasonal variation of selected elements in *Garra lamta* between the two rivers with Range, mean and Standard Deviation.

(December 2004 – November 2005).

Table: 4.7. Correlation study of Fe

Seasons	Range ($\mu\text{g/g}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(47.00-50.10)	(33.84-37.89)	(49.23 \pm 1.33)	(35.87 \pm 2.02)
Spring	(64.90-67.50)	(70.38-74.44)	(66.40 \pm 1.35)	(72.41 \pm 2.03)
Summer	(92.60-98.20)	(78.20-84.26)	(95.50 \pm 2.81)	(81.23 \pm 3.03)
Autumn	(27.50-31.30)	(31.41-33.47)	(29.40 \pm 1.90)	(32.44 \pm 1.03)

Significant Correlation, ($p < 0.10$; $r = 0.93$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.8. Correlation study of Zn

Seasons	Range ($\mu\text{g/g}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(88.50-96.20)	(75.52-77.58)	(92.20 \pm 3.86)	(76.55 \pm 1.03)
Spring	(73.80-84.20)	(60.20-62.26)	(79.56 \pm 5.29)	(61.23 \pm 1.03)
Summer	(94.30-96.40)	(87.18-89.22)	(95.40 \pm 3.92)	(88.20 \pm 1.02)
Autumn	(64.30-69.20)	(56.52-60.56)	(67.00 \pm 2.49)	(58.54 \pm 2.02)

Significant Correlation, ($p < 0.10$; $r = 0.92$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.9. Correlation study of Mn

Seasons	Range ($\mu\text{g/g}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(2.52-2.72)	(3.21-3.35)	(2.62 \pm 0.10)	(3.28 \pm 0.07)
Spring	(6.82-8.58)	(8.34-8.46)	(7.70 \pm 0.52)	(8.40 \pm 0.06)
Summer	(7.55-9.20)	(9.20-9.24)	(8.44 \pm 0.62)	(9.22 \pm 0.02)
Autumn	(6.90-8.00)	(6.39-6.45)	(7.60 \pm 0.61)	(6.42 \pm 0.03)

Significant Correlation, ($p < 0.10$; $r = 0.94$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.10. Correlation study of Cu

Seasons	Range ($\mu\text{g/g}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(0.27-0.30)	(0.41-0.49)	(0.34 \pm 0.03 ^a)	(0.45 \pm 0.04 ^a)
Spring	(0.77-0.89)	(0.66-0.70)	(0.83 \pm 0.06 ^a)	(0.68 \pm 0.02 ^a)
Summer	(0.85-0.89)	(0.78-0.84)	(0.87 \pm 0.04 ^a)	(0.81 \pm 0.03 ^a)
Autumn	(0.62-0.68)	(0.55-0.61)	(0.65 \pm 0.03 ^a)	(0.58 \pm 0.03 ^a)

Significant Correlation, ($p < 0.10$; $r = 0.94$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.11. Correlation study of Ni

Seasons	Range ($\mu\text{g/g}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(0.22-0.28)	(0.18-0.26)	(0.25 \pm 0.03 ^a)	(0.22 \pm 0.04 ^a)
Spring	(0.18-0.22)	(0.19-0.23)	(0.20 \pm 0.02 ^a)	(0.21 \pm 0.04 ^a)
Summer	(0.27-0.29)	(0.28-0.34)	(0.28 \pm 0.02 ^a)	(0.31 \pm 0.03 ^a)
Autumn	(0.08-0.12)	(0.13-0.19)	(0.22 \pm 0.02 ^a)	(0.16 \pm 0.03 ^a)

Significant Correlation, ($p < 0.10$; $r = 0.80$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.12. Correlation study of Co

Seasons	Range ($\mu\text{g/g}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(0.10-0.140)	(0.50-0.54)	(0.76 \pm 0.02 ^a)	(0.52 \pm 0.02 ^a)
Spring	(0.78-0.82)	(0.61-0.69)	(0.80 \pm 0.02 ^a)	(0.65 \pm 0.04 ^a)
Summer	(0.96-0.98)	(0.86-0.96)	(0.97 \pm 0.02 ^a)	(0.91 \pm 0.05 ^a)
Autumn	(0.07-0.11)	(0.74-0.82)	(0.89 \pm 0.02 ^a)	(0.78 \pm 0.04 ^a)

Significant Correlation, ($p < 0.05$; $r = 0.98$). ^aMean \pm Standard Deviation, $n = 3$

**Correlation study of selected elements in *Garra lamta* between the two rivers (December 2004 – November 2005)

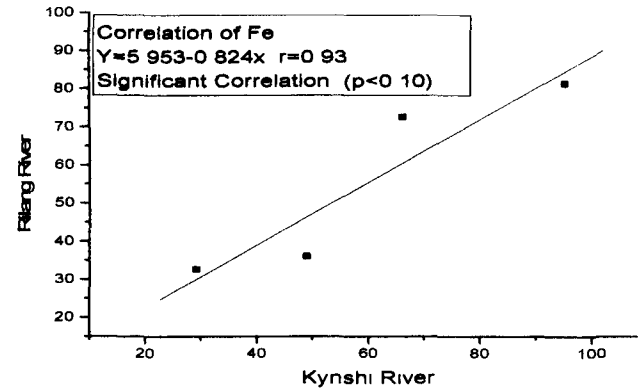
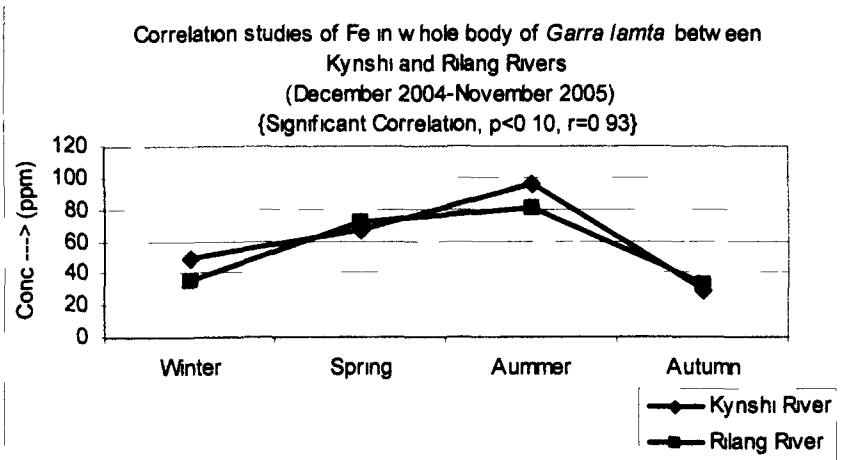


Fig 4 13 & 4 14 Correlation study of Fe

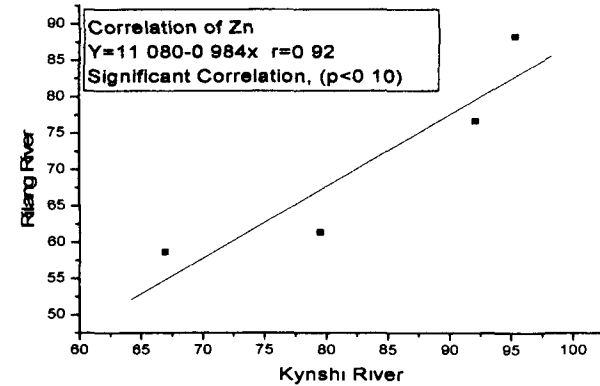
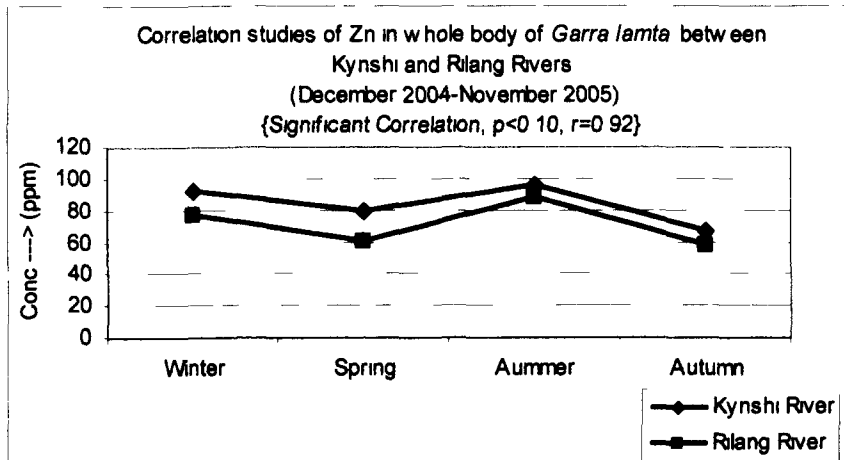


Fig 4 15 & 4 16 Correlation study of Zn

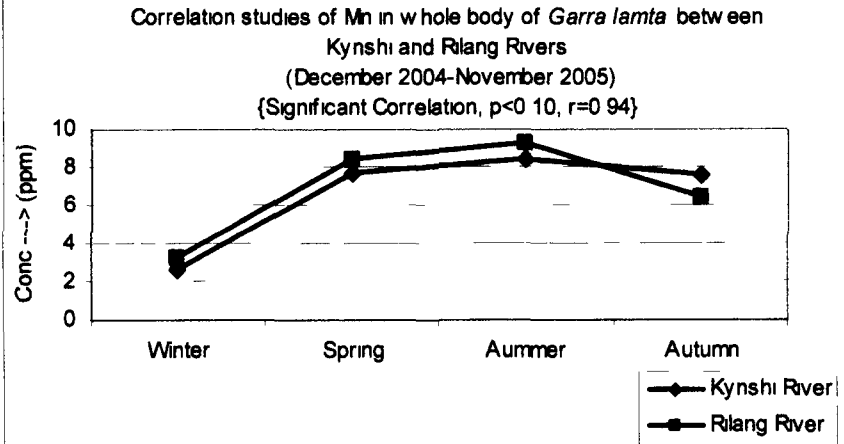


Fig 4 17 & 4 18 Correlation study of Mn

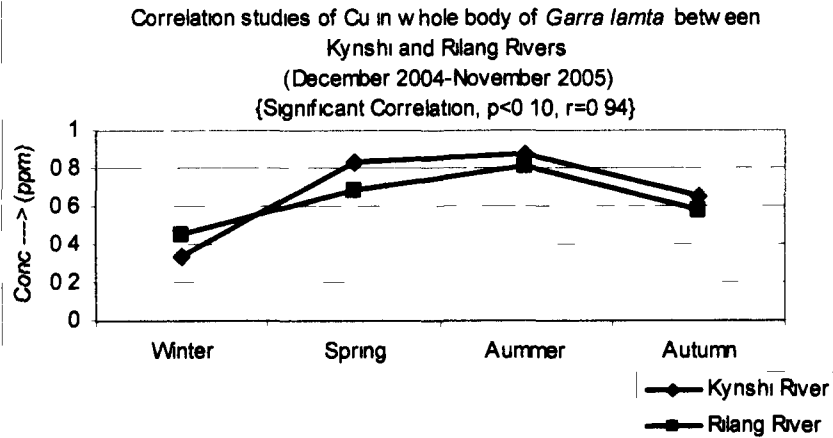
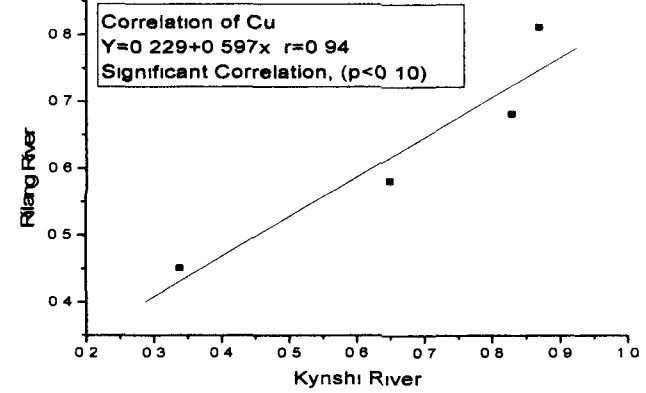
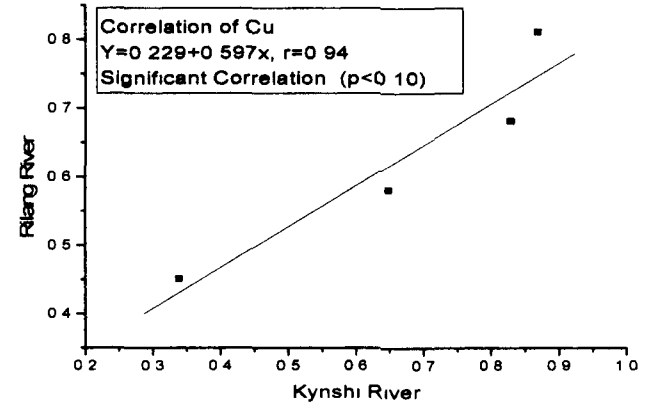


Fig 4 19 & 4 20 Correlation study of Cu



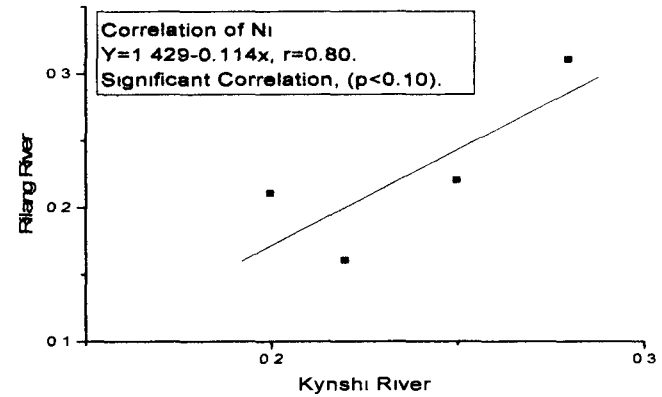
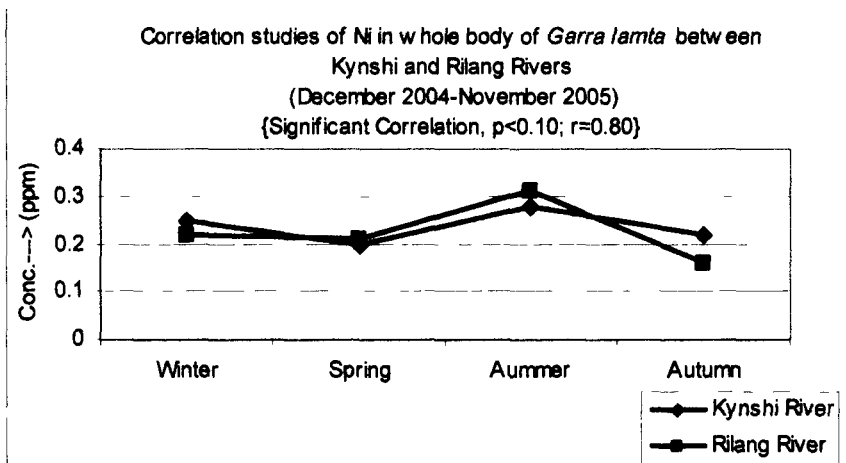


Fig: 4.21 & 4.22. Correlation study of Ni

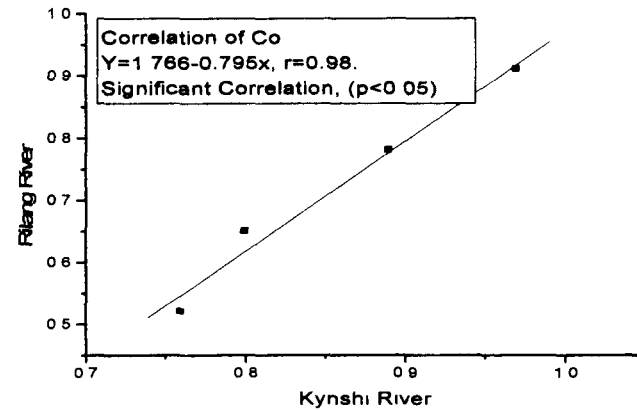
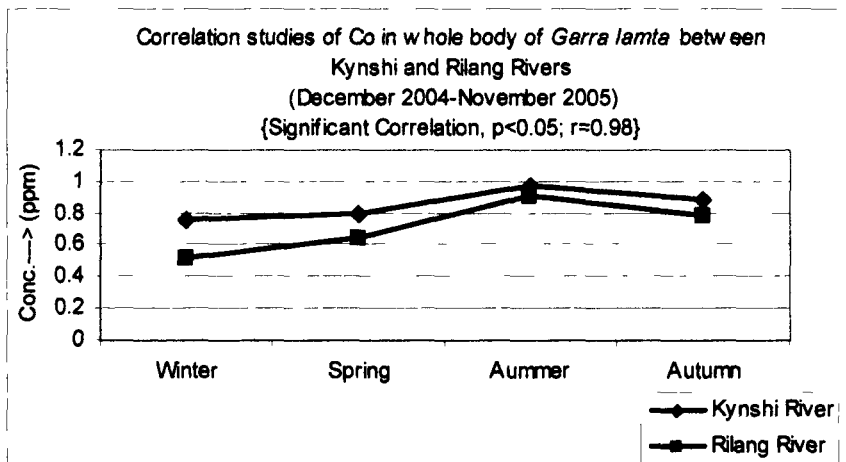


Fig: 4.23 & 4.24. Correlation study of Co

****Correlation study in the Seasonal variation of selected elements in water samples of the two rivers with Range, mean and Standard Deviation.**

(December 2003 – November 2004).

Table: 4.13. Correlation study of Iron Fe

Seasons	Range ($\mu\text{g/l}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(15.65-17.55)	(26.85-30.95)	(16.20 \pm 1.45 ^a)	(28.90 \pm 2.05 ^a)
Spring	(30.55-32.41)	(38.20-44.24)	(31.50 \pm 0.96 ^a)	(41.22 \pm 3.02 ^a)
Summer	(73.67-76.73)	(63.18-67.28)	(75.34 \pm 1.53 ^a)	(65.23 \pm 2.05 ^a)
Autumn	(49.50-50.50)	(56.70-60.72)	(50.33 \pm 1.04 ^a)	(58.71 \pm 2.01 ^a)

Significant Correlation, ($p < 0.05$; $r = 0.97$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.14. Correlation study of Zn

Seasons	Range ($\mu\text{g/l}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(6.75-8.85)	(11.23-15.27)	(8.13 \pm 0.62 ^a)	(13.25 \pm 2.02 ^a)
Spring	(3.50-4.00)	(7.50-9.66)	(7.52 \pm 0.25 ^a)	(8.58 \pm 1.08 ^a)
Summer	(12.50-13.55)	(14.25-18.31)	(13.17 \pm 0.58 ^a)	(16.28 \pm 2.03 ^a)
Autumn	(6.01-6.85)	(3.50-5.54)	(6.56 \pm 0.48 ^a)	(4.52 \pm 1.02 ^a)

Significant Correlation, ($p < 0.10$; $r = 0.86$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.15. Correlation study of Mn

Seasons	Range ($\mu\text{g/l}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(15.22-15.95)	(12.50-14.66)	(15.57 \pm 0.37 ^a)	(13.58 \pm 1.08 ^a)
Spring	(12.14-13.02)	(9.50-11.58)	(12.57 \pm 0.44 ^a)	(10.54 \pm 1.04 ^a)
Summer	(25.11-26.67)	(26.21-30.25)	(26.00 \pm 0.80 ^a)	(28.23 \pm 2.02 ^a)
Autumn	(17.18-18.22)	(20.20-22.24)	(17.65 \pm 0.53 ^a)	(21.22 \pm 1.02 ^a)

Significant Correlation, ($p < 0.05$; $r = 0.96$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.16. Correlation study of Cu

Seasons	Range ($\mu\text{g/l}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(1.32-1.55)	(1.42-1.60)	(1.43 \pm 0.11 ^a)	(1.51 \pm 0.10 ^a)
Spring	(0.95-1.15)	(1.18-1.26)	(1.04 \pm 0.10 ^a)	(1.22 \pm 0.04 ^a)
Summer	(1.65-1.98)	(1.54-1.72)	(1.82 \pm 0.17 ^a)	(1.63 \pm 0.09 ^a)
Autumn	(0.24-0.26)	(1.36-1.50)	(1.26 \pm 0.02 ^a)	(1.43 \pm 0.07 ^a)

Significant Correlation, ($p < 0.05$; $r = 0.95$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.17. Correlation study of Ni

Seasons	Range ($\mu\text{g/l}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(22.15-23.12)	(22.50-26.54)	(22.59 \pm 0.49 ^a)	(24.52 \pm 2.02 ^a)
Spring	(18.11-19.15)	(21.34-24.46)	(18.60 \pm 0.52 ^a)	(23.40 \pm 1.59 ^a)
Summer	(26.56-28.21)	(35.50-37.60)	(27.55 \pm 0.87 ^a)	(36.55 \pm 1.05 ^a)
Autumn	(21.12-22.14)	(15.20-17.24)	(21.71 \pm 0.53 ^a)	(16.22 \pm 1.02 ^a)

Significant Correlation, ($p < 0.05$; $r = 0.98$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.18. Correlation study of Co

Seasons	Range ($\mu\text{g/l}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(6.02-6.98)	(7.48-9.54)	(6.48 \pm 0.48 ^a)	(8.51 \pm 1.03 ^a)
Spring	(8.11-9.12)	(12.18-14.33)	(8.61 \pm 0.51 ^a)	(13.25 \pm 1.07 ^a)
Summer	(13.12-14.06)	(17.48-19.62)	(13.58 \pm 0.47 ^a)	(18.55 \pm 1.11 ^a)
Autumn	(7.03-8.12)	(9.00-11.04)	(7.56 \pm 0.55 ^a)	(10.02 \pm 1.02 ^a)

Significant Correlation, ($p < 0.05$; $r = 0.98$). ^aMean \pm Standard Deviation, $n = 3$

**Correlation study of selected elements between the two rivers (December 2003 – November 2004)

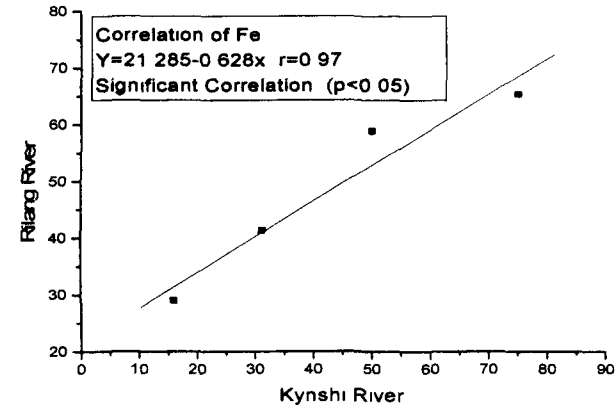
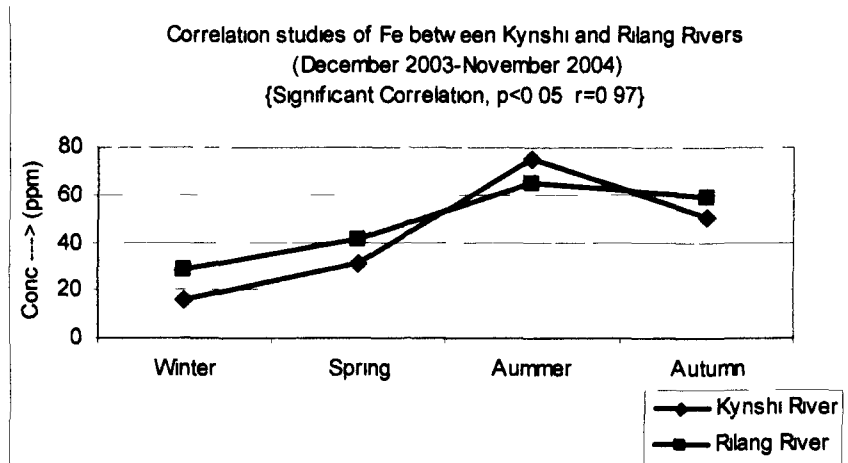


Fig 4 25 & 4 26 Correlation study of Fe

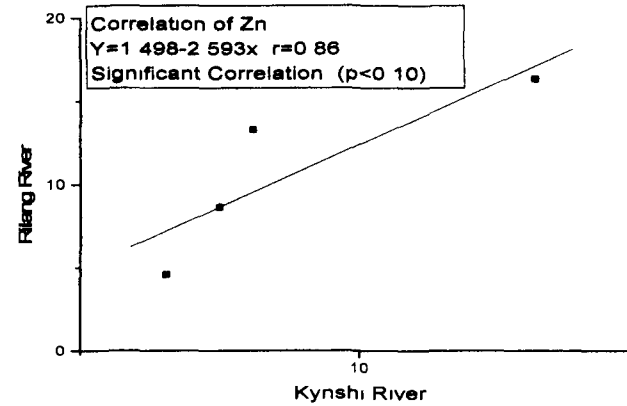
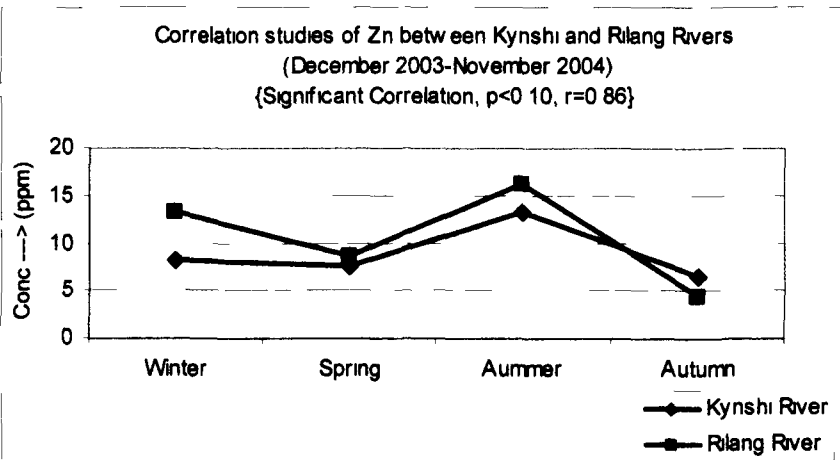


Fig 4 27 & 4 28 Correlation study of Zn

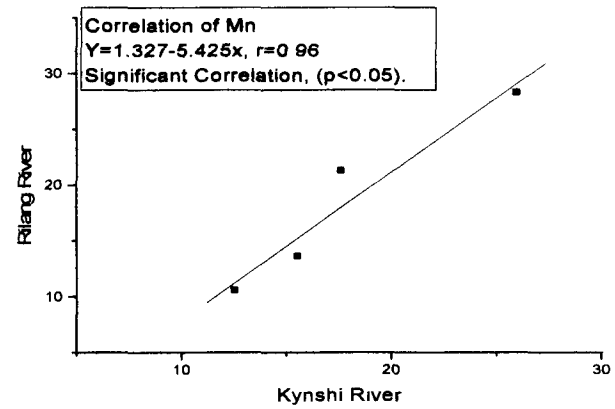
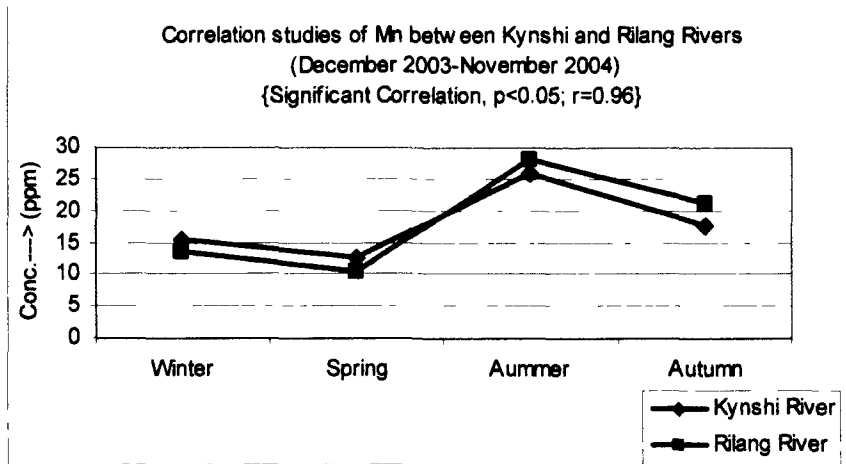


Fig: 4.29 & 4.30. Correlation study of Mn

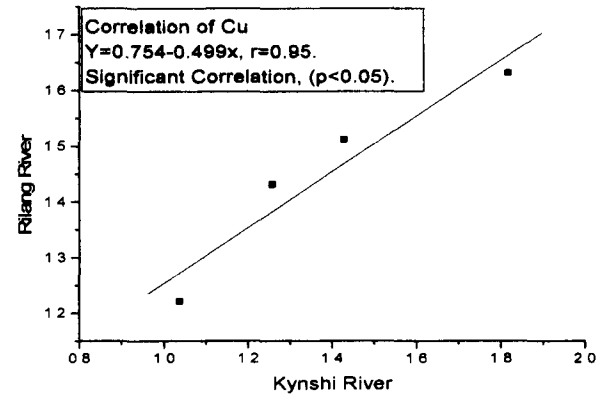
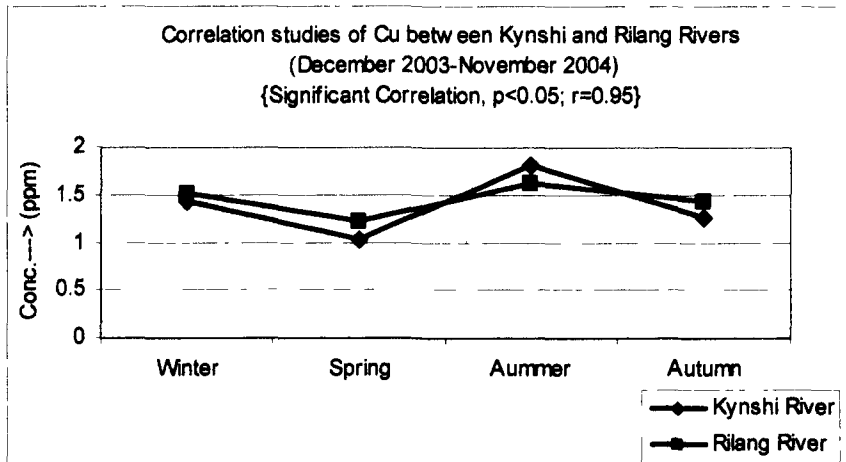


Fig: 4.31 & 4.32. Correlation study of Cu

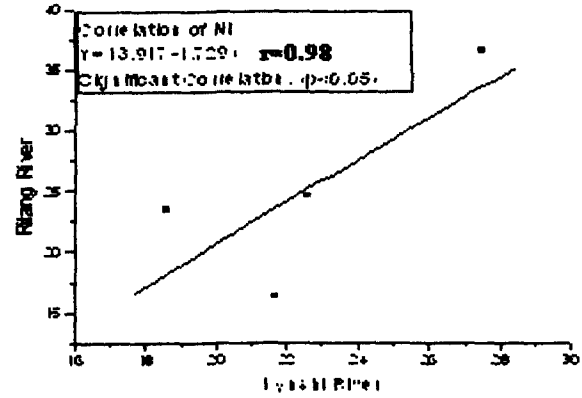
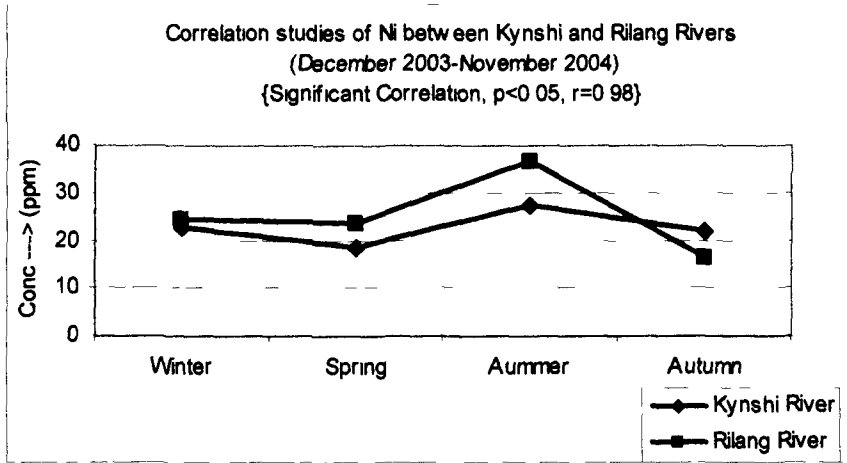


Fig. 4.33 & 4.34. Correlation study of Ni

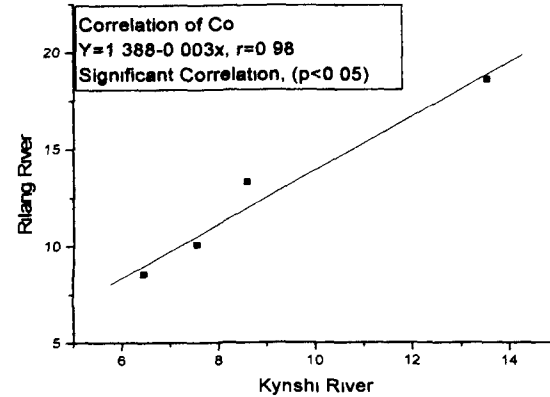
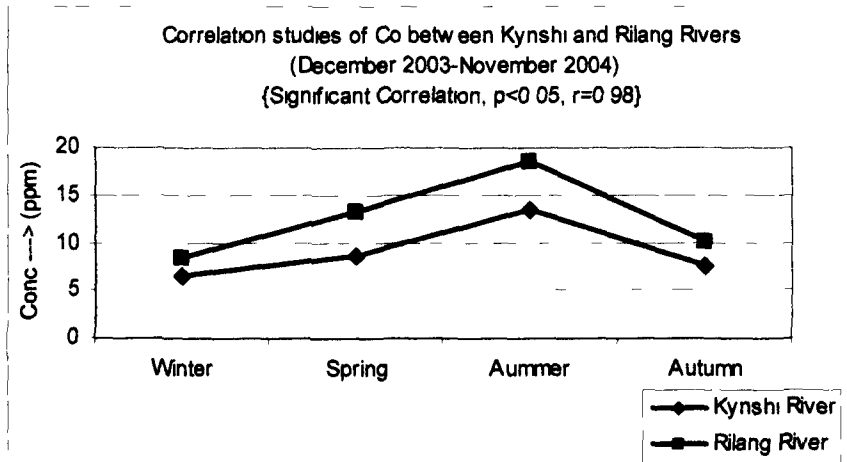


Fig. 4.35 & 4.36 Correlation study of Co

**Correlation study in the Seasonal variation of selected elements in water samples of the two rivers with Range, mean and Standard Deviation.

(December 2004 – November 2005).

Table: 4.19. Correlation study of Iron Fe

Seasons	Range ($\mu\text{g/l}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(22.14-23.25)	(30.09-34.13)	(22.63 \pm 0.57 ^a)	(32.11 \pm 2.02 ^a)
Spring	(15.5-19.22)	(22.20-26.24)	(17.24 \pm 2.12 ^a)	(24.22 \pm 2.02 ^a)
Summer	(44.12-45.91)	(53.50-57.54)	(44.72 \pm 1.03 ^a)	(55.52 \pm 2.02 ^a)
Autumn	(24.90-26.60)	(41.20-43.26)	(25.60 \pm 0.89 ^a)	(42.23 \pm 1.03 ^a)

Significant Correlation, ($p < 0.05$; $r = 0.96$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.20. Correlation study of Zn

Seasons	Range ($\mu\text{g/l}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(6.12-6.84)	(12.20-14.30)	(13.82 \pm 0.36 ^a)	(13.25 \pm 1.05 ^a)
Spring	(13.33-14.60)	(16.20-20.22)	(13.94 \pm 0.64 ^a)	(18.21 \pm 2.01 ^a)
Summer	(17.34-18.72)	(23.20-25.24)	(17.86 \pm 0.75 ^a)	(24.22 \pm 1.02 ^a)
Autumn	(7.30-8.50)	(8.54-10.58)	(8.17 \pm 0.76 ^a)	(9.56 \pm 1.02 ^a)

Significant Correlation, ($p < 0.10$; $r = 0.93$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.21. Correlation study of Mn

Seasons	Range ($\mu\text{g/l}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(13.94-15.31)	(10.20-12.24)	(14.56 \pm 0.69 ^a)	(11.22 \pm 1.02 ^a)
Spring	(15.5-16.90)	(14.16-16.24)	(16.37 \pm 0.76 ^a)	(15.20 \pm 1.04 ^a)
Summer	(25.12-26.92)	(19.20-23.24)	(25.52 \pm 1.40 ^a)	(21.22 \pm 2.02 ^a)
Autumn	(12.13-13.12)	(8.19-10.27)	(12.72 \pm 0.52 ^a)	(9.23 \pm 1.04 ^a)

Significant Correlation, ($p < 0.05$; $r = 0.97$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.22. Correlation study of Cu

Seasons	Range ($\mu\text{g/l}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(1.39-0.42)	(1.16-1.28)	(1.39 \pm 0.03 ^a)	(1.22 \pm 0.06 ^a)
Spring	(1.37-1.43)	(1.24-1.40)	(1.40 \pm 0.03 ^a)	(1.32 \pm 0.08 ^a)
Summer	(2.38-2.79)	(2.52-2.74)	(2.45 \pm 0.22 ^a)	(2.63 \pm 0.11 ^a)
Autumn	(0.52-0.56)	(1.70-1.82)	(1.54 \pm 0.02 ^a)	(1.76 \pm 0.06 ^a)

Significant Correlation, ($p < 0.05$; $r = 0.97$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.23. Correlation study of Ni

Seasons	Range ($\mu\text{g/l}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(14.11-15.98)	(2.45-2.59)	(2.73 \pm 0.98 ^a)	(2.52 \pm 0.07 ^a)
Spring	(17.12-18.13)	(3.00-5.12)	(3.26 \pm 0.51 ^a)	(4.11 \pm 1.06 ^a)
Summer	(24.32-26.11)	(3.63-5.69)	(4.26 \pm 0.91 ^a)	(4.66 \pm 1.03 ^a)
Autumn	(12.14-13.02)	(2.90-3.06)	(3.17 \pm 0.44 ^a)	(2.98 \pm 0.08 ^a)

Significant Correlation, ($p < 0.10$; $r = 0.89$). ^aMean \pm Standard Deviation, $n = 3$

Table: 4.24. Correlation study of Co

Seasons	Range ($\mu\text{g/l}$)		Mean \pm SD	
	Kynshi River	Rilang River	Kynshi River	Rilang River
Winter	(7.13-8.54)	(2.18-4.26)	(7.77 \pm 0.71 ^a)	(3.22 \pm 1.04 ^a)
Spring	(8.58-10.11)	(3.11-5.19)	(9.37 \pm 0.77 ^a)	(4.15 \pm 1.04 ^a)
Summer	(12.44-13.98)	(6.48-8.54)	(13.29 \pm 0.78 ^a)	(7.51 \pm 1.03 ^a)
Autumn	(11.12-11.89)	(5.42-7.46)	(11.19 \pm 0.68 ^a)	(6.44 \pm 1.02 ^a)

Significant Correlation, ($p < 0.05$; $r = 0.98$). ^aMean \pm Standard Deviation, $n = 3$

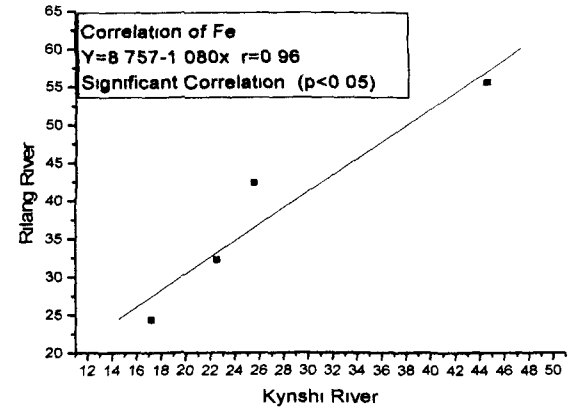
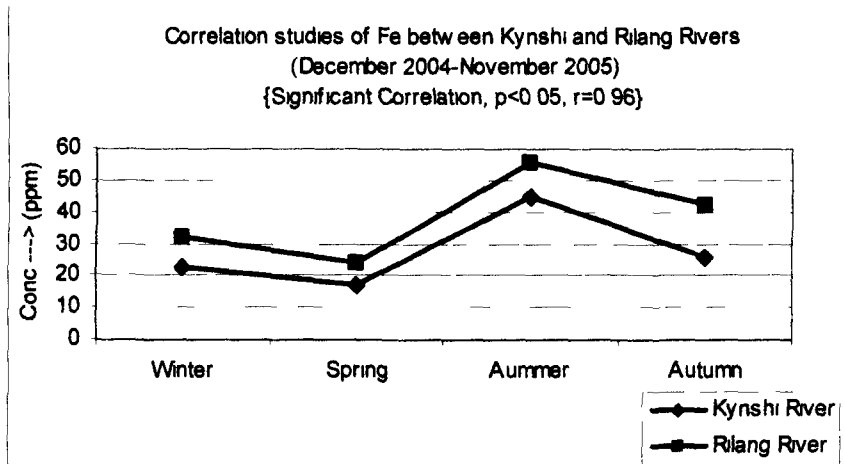


Fig 4 37 & 4 38 Correlation study of Fe

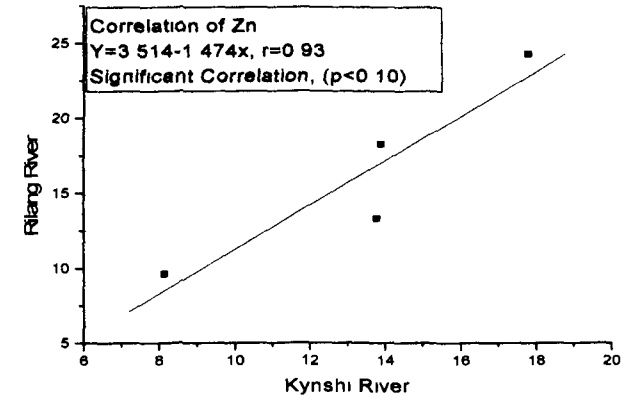
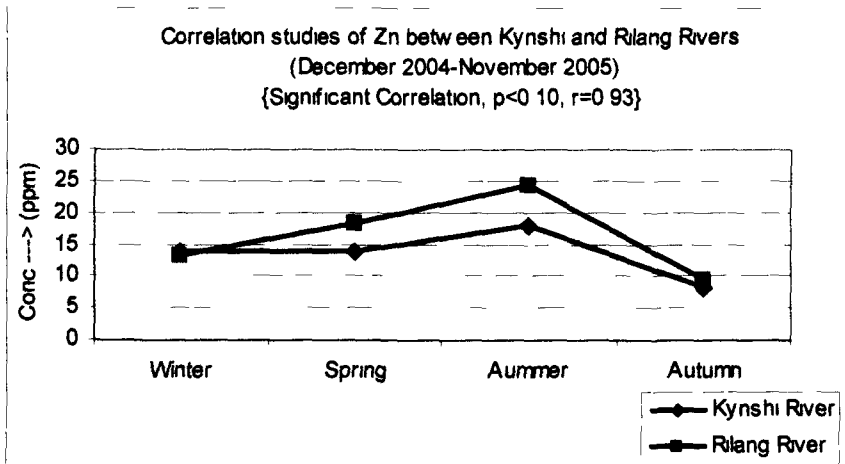


Fig 4 39 & 4 40 Correlation study of Zn

Correlation studies of Mn between Kynshi and Rilang Rivers
(December 2004-November 2005)
{Significant Correlation, $p < 0.05$; $r = 0.97$ }

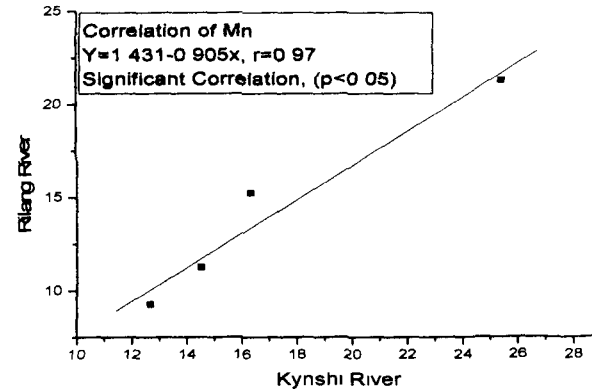
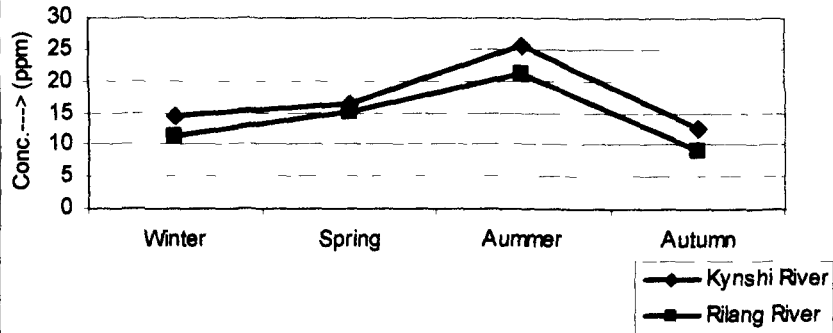


Fig: 4.41 & 4.42. Correlation study of Mn

Correlation studies of Cu between Kynshi and Rilang Rivers
(December 2004-November 2005)
{Significant Correlation, $p < 0.05$; $r = 0.97$ }

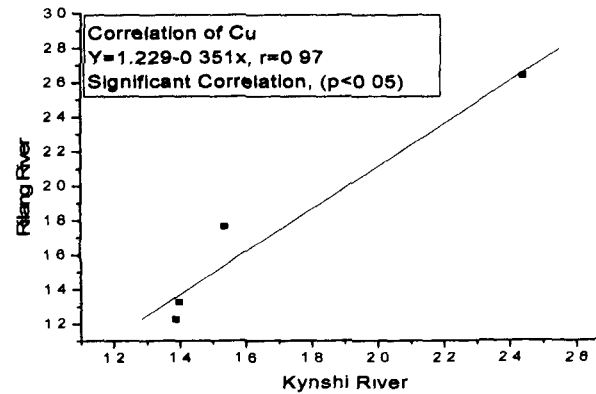
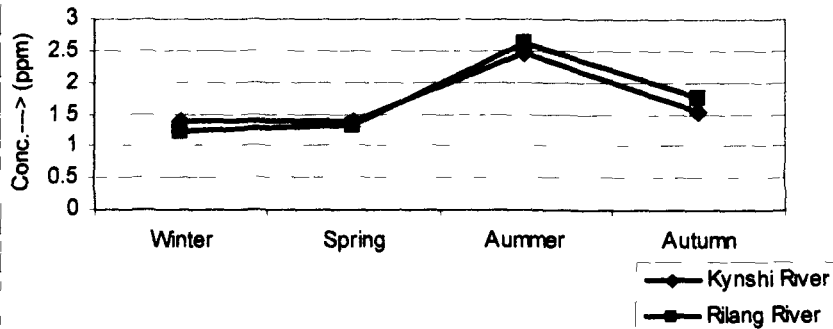


Fig: 4.43 & 4.44. Correlation study of Cu

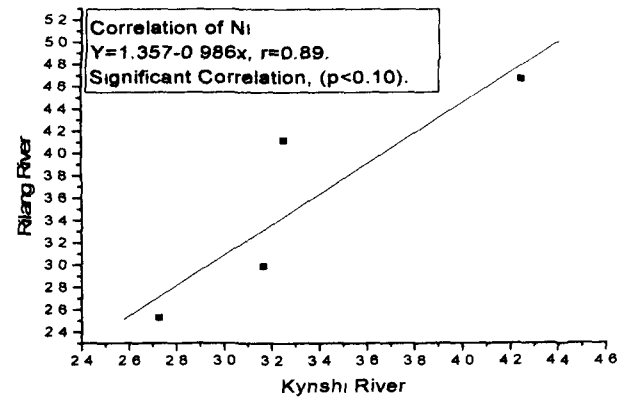
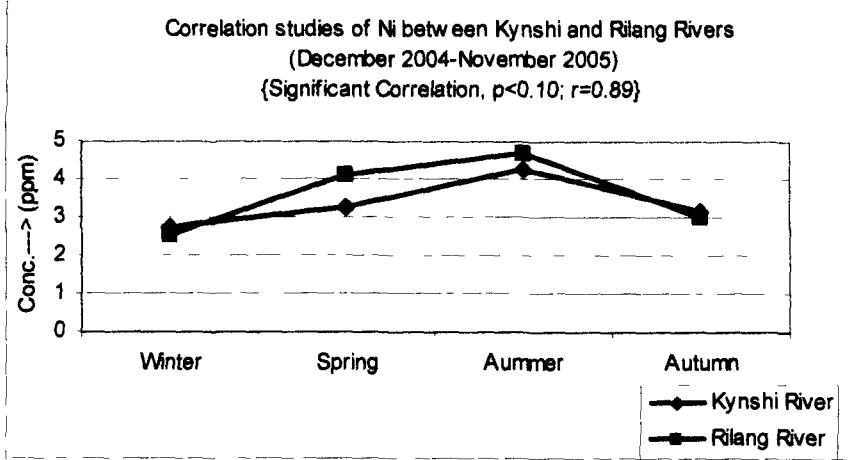


Fig: 4.45 & 4.46. Correlation study of Cu

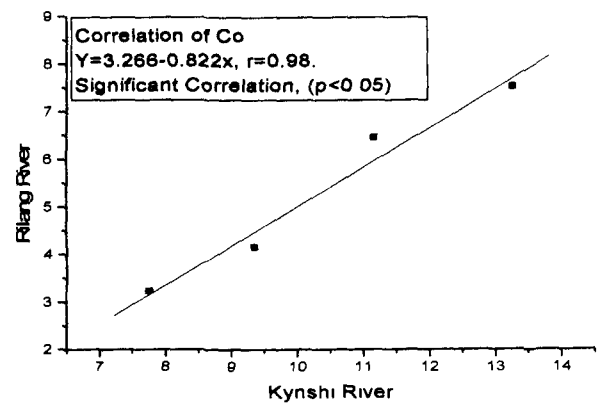
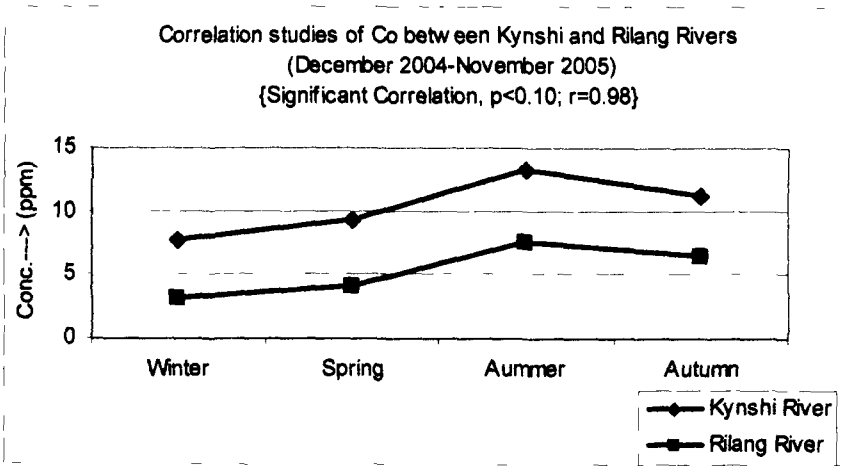


Fig: 4.47 & 4.48. Correlation study of Co

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Chapter-V
(Abiotic parameters)

Introduction

In the natural environment carbonate alkalinity tends to make up most of the total alkalinity due to the common occurrence and dissolution of carbonate rocks and presence of carbon dioxide in the atmosphere. Other common natural components that can contribute to alkalinity include borate, hydroxide, phosphate, silicate, nitrate, dissolved ammonia, the conjugate bases of some organic acids and sulfide (Peavy *et al.*, 1987; Vermani and Narula, 1989; Sharma and Kaur, 1998; Manivasakam, 1984; Pande and Sharma, 1999). The earth's basic air envelope is made up of about 21% Oxygen. Concentrations of these gases within water are a whole different story. The concentrations are much smaller and are measured in milligrams per liter (mg/l) or somewhat equivalently, in parts per million (ppm). As the air components dissolve into the water, a point is reached where no more can be added. This point is called saturation. The saturation points are different for each of the gases and are dependent upon several different factors but temperature is the most important. As the temperature increases, oxygen concentrations decrease (Sharma *et al.*, 1996; Grasshoff, 1983; Abbasi *et al.*, 1996; Srikant *et al.*, 1995).

Alkalinity estimation

Water samples were collected using acid washed polyethylene plastic containers with screw caps and amber glass bottles. Washing procedures for containers were as recommended in standard methods for waters and wastewaters (APHA, 1998). For general parameters determination, 1 L High Density Polyethylene (HDPE) is used.

Requirements:

I. 0.02N H₂SO₄, Methyl orange, Phenolphthalein.

Procedure

50ml of water samples are taken in a conical Flask, two drops of Phenolphthalein are added, if pink colour appears we have to titrate against 0.02N H₂SO₄, till the colour disappeared. If no pink colours appears, 2-3 drops of methyl orange are added and titrate against the same titrant till pink colour developed. The same experiments are repeated for three times.

Calculation

$$\text{Total Alkalinity (mg/l)} = \frac{\text{Volume of titrant} \times 1000}{\text{Volume of sample}}$$

Dissolved oxygen Estimation by Winkler's method

Requirements:

I. 0.025N Na₂S₂O₃ solution

II. Alkaline Potassium Iodide

III. MnSO₄

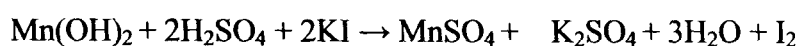
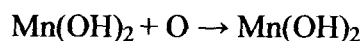
IV. Burette, Pipette, Conical Flask, measuring cylinder, 125ml BOD Bottles

Water are collected in 125ml BOD Bottles without air bubbles, 1ml of MnSO₄ are added followed by 1ml alkaline Potassium Iodide (KI) and shake well. Precipitate is allowed to settle for 10 minutes, 1 ml of concentrate H₂SO₄ are added and the precipitate are dissolved by shaking, brown solution is formed.

25ml of the above solution are taken in a conical flask and 2-3 drop of starch solution was added and the solution developed a blue colour. This solution was then titrated against 0.025N Na₂S₂O₃ till it becomes colourless and the volume of titrant used is noted. This experiment is repeated three times.

Principle

Oxygen combines with Mn(OH)₂ to form higher Hydroxide which on acidification liberates Iodine equivalent to that of Oxygen fixed. This is then titrated with standard Na₂S₂O₃ using starch as indicator.



Calculation

$$\text{Dissolve oxygen (mg/l)} = \frac{8 \times 1000 \times 0.025 \text{N} \times \text{Volume of titrant}}{\text{Volume of sample}}$$

pH and Temperature

pH and temperature of the water samples are measured using portable pH tester and thermometer.

Statistical Analysis: One-Way ANOVA test are used for the statistical analysis of the data.

Alkalinity

The study shows that in the year 2003-2004 mean alkalinity in winter in the water bodies of kynshi river are 16.5 ± 2.2 mg/l with a range of 14.3-18.7 mg/l. During spring it has a mean of 18.0 ± 2.0 mg/l with a range of 16.0-20.0 mg/l. In summer it ranges from 21.2-25.8 mg/l with a mean of 23.5 ± 2.3 mg/l, where as during autumn it ranges from 19.1-23.9 mg/l with a mean of 21.5 ± 2.4 mg/l (Table: 5.1). Statistical analysis of the data shows that there is a significant variation, ($p < 0.05$; $F_{3,8} = 6.171$). In the year 2004-2005 mean alkalinity in winter are 17.0 ± 2.0 mg/l and it ranges from 15.0-19.0 mg/l. During spring it varies from 18.2-22.8 mg/l with a mean of 20.5 ± 2.3 mg/l. In summer it varies from 22.0-26.0 mg/l with a mean of 24.0 ± 2.0 . In autumn it has a mean of 19.5 ± 2.4 mg/l with a range of 17.1-21.9 mg/l (Table: 5.2). Statistical analysis of the data shows that there is a significant variation, ($p < 0.05$; $F_{3,8} = 6.728$). Seasonal variations of alkalinity for the year 2003-2004 and 2004-2005 from Rilang River are depicted in Table: 5.3 and 5.4 respectively. Seasonal variations of alkalinity from both the rivers for the year 2003-2004 and 2004-2005 are represented graphically in Fig: 5.1 & Fig: 5.2.

Total alkalinity is the total concentration of bases in water expressed as parts per million (ppm) or milligrams per liter (mg/l) of calcium carbonate (CaCO_3). These bases are usually bicarbonates (HCO_3) and carbonates (CO_3), and they act as a buffer system that prevents drastic changes in pH. For example, in waters with low alkalinity, pH might fluctuate from 6 or lower to as high as 10 or above; while in high alkalinity waters, pH



might fluctuate from about 7.5 to 8.5. Total alkalinity ranges 16.50-24.70 mg/l in the sampled aquatic ecosystems. Alkalinity is, however, primarily attributed presently to methyl orange alkalinity, which in turn is attributed to bicarbonate ions. The stated salient feature represented a characteristic attribute of acidic-circum neutral waters (Kalf, 2002) and also corresponded with identical results from several biotopes of N. E. India (Sharma *et al.*, 2004).

Waters with low alkalinity are very susceptible to changes in pH. Waters with high alkalinity are able to resist major shifts in pH. As increasing amounts of acid are added to a water body, the pH of the water decreases, and the buffering capacity of the water is consumed. If natural buffering materials are present, pH will drop slowly to around 6; then a rapid pH drop occurs as the bicarbonate buffering capacity (CO_3^{2-} and HCO_3^-) is used up. At pH 5.5, only very weak buffering ability remains, and the pH drops further with additional acid. A solution having a pH below 4.5 contains no alkalinity, because there are no CO_3^{2-} or HCO_3^- ions left (Mueller and Helsel, 1999; Hem, 1985). Carbonates are added to a water system if the water passes through soil and rock that contain carbonate minerals, such as calcite (CaCO_3), where limestone and sedimentary rocks and carbonate-rich soils are predominant, where as igneous rocks such as granite and carbonate-poor soils are predominant waters will have low alkalinity. Because alkalinity varies greatly due to differences in geology, there are no general standards for alkalinity. Levels of 20-200 mg/L are typical for fresh water. A total alkalinity level of 100-200 mg/L will stabilize the pH level in a stream. Levels below 10 mg/L indicate that the system is poorly buffered, and is very susceptible to changes in pH from natural and human-caused source.

Table: 5.1. Seasonal variation of Alkalinity (mg/l) in water samples of Kynshi River (Dec' 2003 – Nov' 2004)

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(14.3-18.7)	(16.5 \pm 2.2 ^a)
Spring	(16.0-20.0)	(18.0 \pm 2.0 ^a)
Summer	(21.2-25.8)	(23.5 \pm 2.3 ^a)
Autumn	(19.1-23.9)	(21.5 \pm 2.4 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 6.171$). ^aMean \pm Standard Deviation, $n=3$

Table: 5.2. Seasonal variation of Alkalinity (mg/l) in water samples of Kynshi River (Dec' 2004 – Nov' 2005)

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(15.0-19.0)	(17.0 \pm 2.0 ^a)
Spring	(18.2-22.8)	(20.5 \pm 2.3 ^a)
Summer	(22.0-26.0)	(24.0 \pm 2.0 ^a)
Autumn	(17.1-21.9)	(19.5 \pm 2.4 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 6.728$). ^aMean \pm Standard Deviation, $n=3$

Table: 5.3. Seasonal variation of Alkalinity (mg/l) in water samples of Rilang River (Dec' 2003 – Nov' 2003)

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(17.0-21.0)	(19.0 \pm 2.0 ^a)
Spring	(19.0-23.0)	(21.0 \pm 2.0 ^a)
Summer	(22.9-26.5)	(24.7 \pm 1.8 ^a)
Autumn	(21.5-23.5)	(22.5 \pm 1.0 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 5.680$). ^aMean \pm Standard Deviation, $n=3$

Table: 5.4. Seasonal variation of Alkalinity (mg/l) in water samples of Rilang River (Dec' 2004 – Nov' 2005)

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(14.3-18.7)	(16.5 \pm 2.2 ^a)
Spring	(18.7-22.7)	(20.7 \pm 2.0 ^a)
Summer	(21.5-25.5)	(23.5 \pm 2.0 ^a)
Autumn	(17.3-21.9)	(19.6 \pm 2.3 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 5.544$). ^aMean \pm Standard Deviation, $n=3$

Dissolved Oxygen

Dissolved oxygen concentration of the water bodies in the year 2003-2004 in different seasons are: During winter mean dissolve oxygen is 5.5 ± 1.2 mg/l with a range of 4.3-6.7 mg/l. During spring it has a mean of 7.5 ± 1.3 mg/l with a range of 6.2-8.8 mg/l. In summer it ranges from 7.3-9.7 mg/l with a mean of 8.5 ± 1.2 mg/l, where as during autumn it ranges from 5.0-7.0 mg/l with a mean of 6.0 ± 1.0 mg/l. It shows significant variation, ($p<0.05$; $F_{3,8}=4.084$) (Table: 5.5). In the year 2004-2005 mean dissolve oxygen in winter are 7.5 ± 1.3 mg/l and it ranges from 6.2-8.8 mg/l. During spring it varies from 7.0-9.0 mg/l with a mean of 8.0 ± 1.0 mg/l. In summer it varies from 6.5-10.5 mg/l with a mean of 8.5 ± 2.0 mg/l. In autumn it has a mean of 6.5 ± 1.2 mg/l with a range of 5.3-7.7 mg/l (Table: 5.6). It shows significant variation of oxygen concentration, ($p<0.05$; $F_{3,8}=6.689$). Seasonal variations of dissolved oxygen for the year 2003-2004 and 2004-2005 from Rilang River are depicted in Table: 5.7 and 5.8 respectively. Seasonal variations of Dissolved oxygen from both the rivers for the year 2003-2004 and 2004-2005 are represented graphically in Fig: 5.3 & Fig: 5.4. Adequate dissolved oxygen is necessary for good water quality. Oxygen is a necessary element to all forms of life. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below 5.0 mg/l, aquatic life are put under stress, the lower the concentration, the greater the stress. Oxygen levels that remain below 1-2 mg/l for a few hours can result in into toxic levels for many fish species leading to death (Wetzel and Likens, 2006).

Table: 5.5. Seasonal variation of Dissolve Oxygen (mg/l) in water samples of Kynshi River (Dec' 2003 – Nov' 2004)

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(4.3-6.7)	(5.5 \pm 1.2 ^a)
Spring	(6.2-8.8)	(7.5 \pm 1.3 ^a)
Summer	(7.3-9.7)	(8.5 \pm 1.2 ^a)
Autumn	(5.0-7.0)	(6.0 \pm 1.0 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 4.084$). ^aMean \pm Standard Deviation, $n=3$

Table: 5.6. Seasonal variation of Dissolve Oxygen (mg/l) in water samples of Kynshi River (Dec' 2004 – Nov' 2005)

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(6.2-8.8)	(7.5 \pm 1.3 ^a)
Spring	(7.0-9.0)	(8.0 \pm 1.0 ^a)
Summer	(6.5-10.5)	(8.5 \pm 2.0 ^a)
Autumn	(5.3-7.7)	(6.5 \pm 1.2 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 6.689$). ^aMean \pm Standard Deviation, $n=3$

Table: 5.7. Seasonal variation of Dissolve Oxygen (mg/l) in water samples of Rilang River (Dec' 2003 – Nov' 2004)

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(4.2-6.6)	(5.4 \pm 1.2 ^a)
Spring	(6.3-8.7)	(7.5 \pm 0.96)
Summer	(7.1-9.5)	(8.3 \pm 1.2 ^a)
Autumn	(5.0-7.0)	(6.0 \pm 1.0 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 4.015$). ^aMean \pm Standard Deviation, $n=3$

Table: 5.8. Seasonal variation of Dissolve Oxygen (mg/l) in water samples of Rilang River (Dec' 2004 – Nov' 2005)

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(6.0-8.0)	(7.0 \pm 1.0 ^a)
Spring	(6.2-8.6)	(7.4 \pm 1.2 ^a)
Summer	(7.0-9.0)	(8.0 \pm 1.0 ^a)
Autumn	(5.3-7.7)	(6.5 \pm 1.2 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 6.989$). ^aMean \pm Standard Deviation, $n=3$

pH

pH concentration of the water bodies in the year 2003-2004 in different seasons are: During winter mean pH is 5.80 ± 1.0 with a range of 4.80-6.80. During spring it has a mean of 6.33 ± 1.03 with a range of 5.30-7.36. In summer it ranges from 5.70-7.80 with a mean of 6.75 ± 1.05 , where as during autumn it ranges from 5.10-7.18 with a mean of 6.14 ± 1.04 (Table: 5.9). Statistical analysis of the data shows that there is no significant variation, ($p < 0.05$; $F_{3,8} = 0.2199$). In the year 2004-2005 mean pH in winter are 6.12 ± 1.02 and it ranges from 5.10-7.14. During spring it varies from 5.42-7.46 with a mean of 6.44 ± 1.02 . In summer it varies from 5.65-7.75 with a mean of 6.70 ± 1.05 . In autumn it has a mean of 6.25 ± 0.03 with a range of 6.22-6.28 (Table: 5.10). It shows no significant variation, ($p < 0.05$; $F_{3,8} = 0.5806$), Seasonal variations of pH for the year 2003-2004 and 2004-2005 from Rilang River are depicted in Table: 5.11 and 5.12 respectively. Seasonal variations of pH from both the rivers for the year 2003-2004 and 2004-2005 are represented graphically in Fig: 5.5 & Fig: 5.6.

In general, the nature of water bodies in the study areas and extent of pH variations confirmed with observations in various aquatic biotopes of the state of Meghalaya (Sharma *et al.*, 2004) and elsewhere in Northeastern India (Sharma, 2001).

Table: 5.9. Seasonal variation of pH in water samples of Kynshi River (Dec' 2003 – Nov' 2004)

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(4.80-6.80)	(5.80 \pm 1.00 ^a)
Spring	(5.30-7.36)	(6.33 \pm 1.03 ^a)
Summer	(5.70-7.80)	(6.75 \pm 1.05 ^a)
Autumn	(5.10-7.18)	(6.14 \pm 1.04 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 0.2199$). ^aMean \pm Standard Deviation, $n=3$

Table: 5.10. Seasonal variation of pH in water samples of Kynshi River (Dec' 2004– Nov' 2005)

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(5.10-7.14)	(6.12 \pm 1.02 ^a)
Spring	(5.42-7.46)	(6.44 \pm 1.02 ^a)
Summer	(5.65-7.75)	(6.70 \pm 1.05 ^a)
Autumn	(6.22-6.28)	(6.25 \pm 0.03 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 0.5806$). ^aMean \pm Standard Deviation, $n=3$

Table: 5.11. Seasonal variation of pH in water samples of Rilang River (Dec' 2003 – Nov' 2004)

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(5.5-6.5)	(6.0 \pm 0.5 ^a)
Spring	(5.36-7.44)	(6.40 \pm 1.4 ^a)
Summer	(5.4-7.8)	(6.6 \pm 1.2 ^a)
Autumn	(5.11-7.19)	(6.15 \pm 1.04 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 0.4437$). ^aMean \pm Standard Deviation, $n=3$

Table: 5.12. Seasonal variation of pH in water samples of Rilang River (Dec' 2004– Nov' 2005)

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(4.85-6.95)	(5.90 \pm 1.05 ^a)
Spring	(5.5-7.9)	(6.7 \pm 1.2 ^a)
Summer	(5.87-7.93)	(6.90 \pm 1.03 ^a)
Autumn	(5.06-7.14)	(6.10 \pm 0.73 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 0.2393$). ^aMean \pm Standard Deviation, $n=3$

Temperature

Temperature of the water bodies in the year 2003-2004 in different seasons are: During winter mean is 16.4 ± 2.20 with a range of 14.2-18.6. During spring it has a mean of 18.5 ± 1.20 with a range of 17.3-19.7. In summer it ranges from 20.1-24.9 with a mean of 22.5 ± 2.40 , where as during autumn it ranges from 16.0-18.0 with a mean of 17.0 ± 1.00 (Table: 5.13). Statistical analysis of the data shows that there is a significant variation, ($p < 0.05$; $F_{3,8} = 29.32$). In the year 2004-2005 mean temperature in winter are 15.5 ± 1.20 and it ranges from 14.3-16.7. During spring it varies from 16.0-19.0 with a mean of 17.0 ± 1.50 . In summer it varies from 18.2-22.8 with a mean of 20.5 ± 2.30 . In autumn it has a mean of 17.5 ± 1.20 with a range of 16.3-18.7 (Table: 5.14). It shows significant variation, ($p < 0.05$; $F_{3,8} = 8.038$), Seasonal variations of temperature for the year 2003-2004 and 2004-2005 from Rilang River are depicted in Table: 5.15 and 5.16 respectively. Seasonal variations of alkalinity from both the rivers for the year 2003-2004 and 2004-2005 are represented graphically in Fig: 5.7 & Fig: 5.8.

Conclusion

To sum up, the present observations indicated significant variation in the abiotic parameters (Alkalinity, Dissolved oxygen, pH and temperature) of the water bodies of both the study sites. The variations in water temperature affirm “subtropical nature” of the sampled habitats and, in turn, also concur with the results of subtropical environs of N. E. India. Further, marginally higher mean values noticed presently than other aquatic environs of Meghalaya are attributed to shallow nature of the monitored study sites (Sharma, 2001) and Sharma *et al.*, (2004).

Table: 5.13. Seasonal variation of Temperature ($^{\circ}\text{C}$) in water samples of Kynshi River (Dec' 2003– Nov' 2004)

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(14.2-18.6)	(16.4 \pm 2.20 ^a)
Spring	(17.3-19.7)	(18.5 \pm 1.20 ^a)
Summer	(20.1-24.9)	(22.5 \pm 2.40 ^a)
Autumn	(16.0-18.0)	(17.0 \pm 1.00 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 29.32$). ^aMean \pm Standard Deviation, $n=3$

Table: 5.14. Seasonal variation of Temperature ($^{\circ}\text{C}$) in water samples of Kynshi River (Dec' 2004– Nov' 2005)

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(14.3-16.7)	(15.5 \pm 1.20 ^a)
Spring	(16.0-19.0)	(17.0 \pm 1.50 ^a)
Summer	(18.2-22.8)	(20.5 \pm 2.30 ^a)
Autumn	(16.3-18.7)	(17.5 \pm 1.20 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 8.03$). ^aMean \pm Standard Deviation, $n=3$

Table: 5.15. Seasonal variation of Temperature ($^{\circ}\text{C}$) in water samples of Rilang River (Dec' 2003– Nov' 2004)

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(15.2-17.6)	(16.4 \pm 1.02 ^a)
Spring	(16.0-18.0)	(17.0 \pm 1.00 ^a)
Summer	(21.2-23.8)	(22.5 \pm 1.30 ^a)
Autumn	(18.0-20.0)	(19.0 \pm 1.00 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 6.39$). ^aMean \pm Standard Deviation, $n=3$

Table: 5.16. Seasonal variation of Temperature ($^{\circ}\text{C}$) in water samples of Rilang River (Dec' 2004– Nov' 2005)

Seasons	Range ($\mu\text{g/g}$)	Mean \pm SD
Winter	(14.5-16.9)	(15.7 \pm 1.20 ^a)
Spring	(16.0-18.0)	(17.0 \pm 1.00 ^a)
Summer	(20.1-22.9)	(21.5 \pm 1.40 ^a)
Autumn	(16.1-20.5)	(18.3 \pm 2.20 ^a)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 8.55$). ^aMean \pm Standard Deviation, $n=3$

Seasonal variation of Abiotic parameters water samples of Kynshi and Rilang river

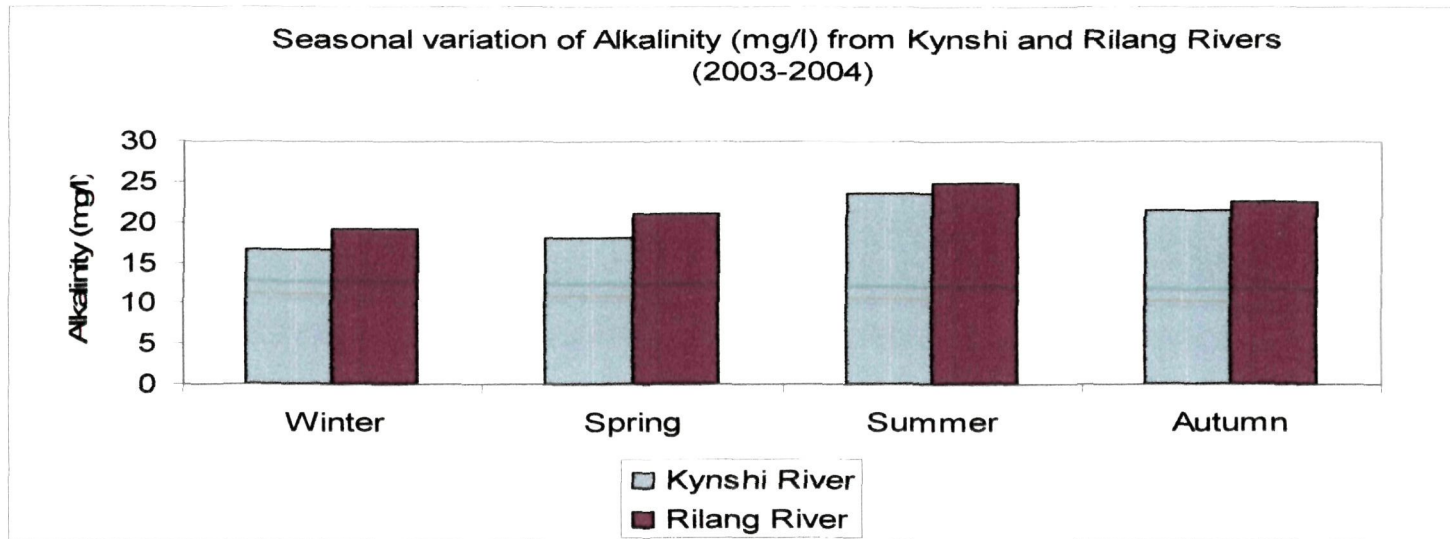


Fig: 5.1. Seasonal variation of Alkalinity from Kynshi and Rilang Rivers (2003-2004)

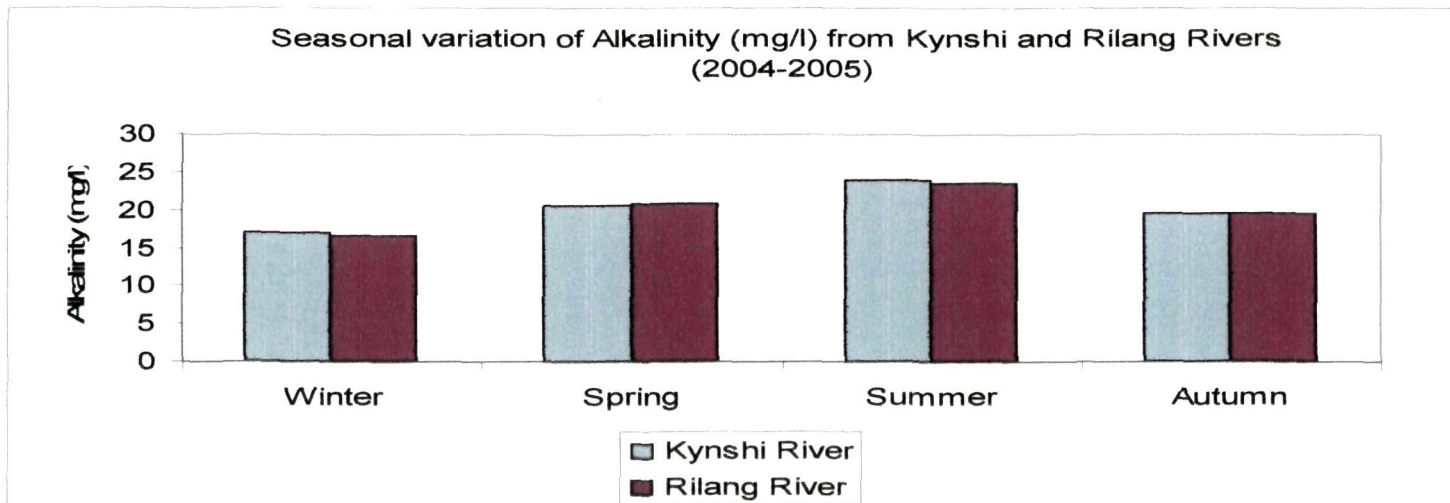


Fig: 5.2. Seasonal variation of Alkalinity from Kynshi and Rilang Rivers (2004-2005)

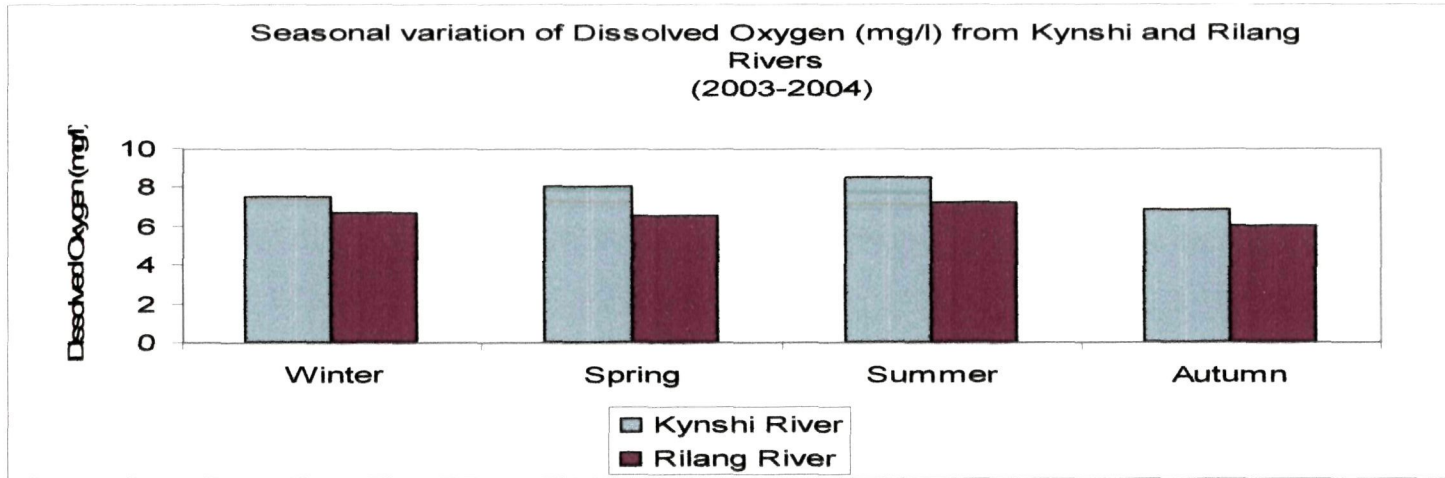


Fig: 5.3. Seasonal variation of Dissolved Oxygen from Kynshi and Rilang Rivers (2003-2004)

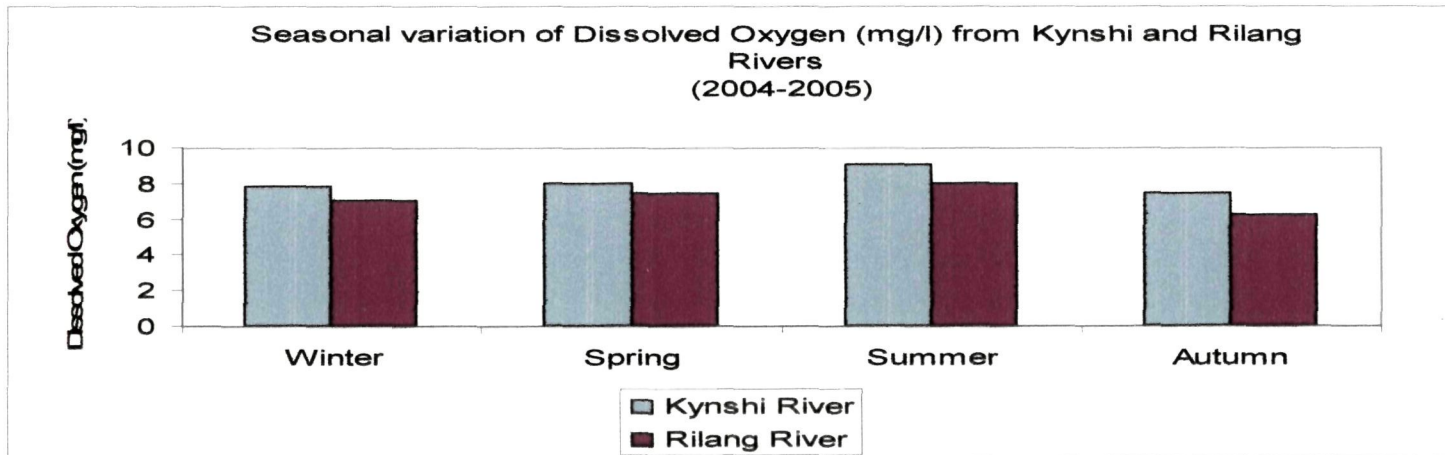


Fig: 5.4. Seasonal variation of Dissolved Oxygen from Kynshi and Rilang Rivers (2004-2005)

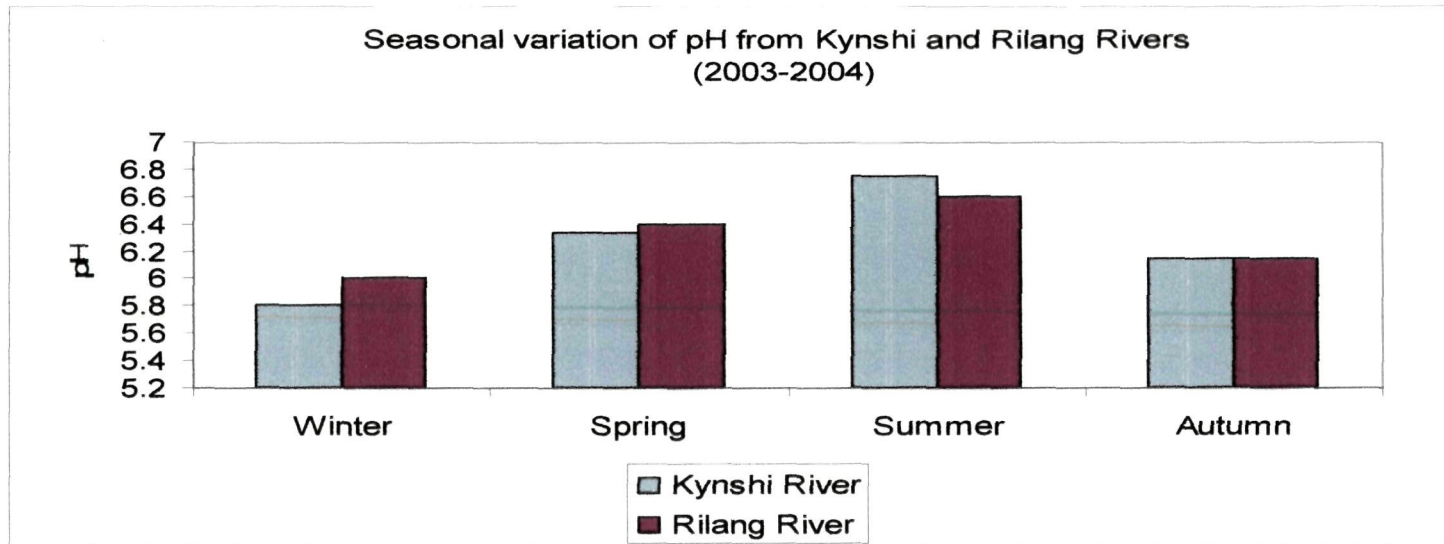


Fig: 5.5. Seasonal variation of pH from Kynshi and Rilang Rivers (2003-2004)

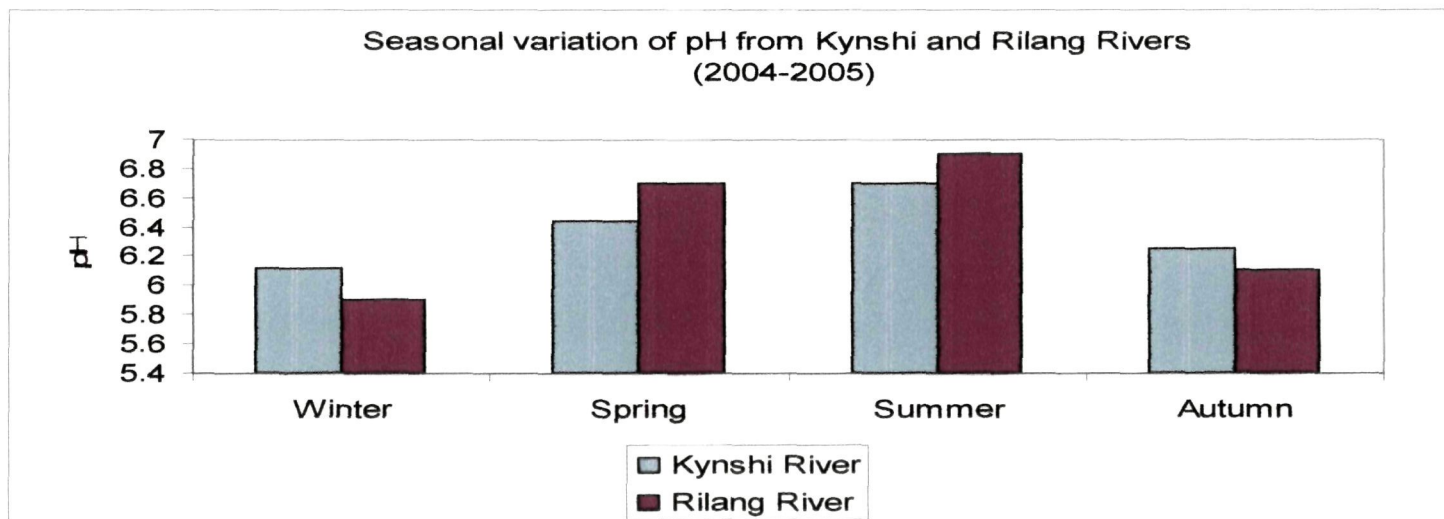


Fig: 5.6. Seasonal variation of pH from Kynshi and Rilang Rivers (2004-2005)

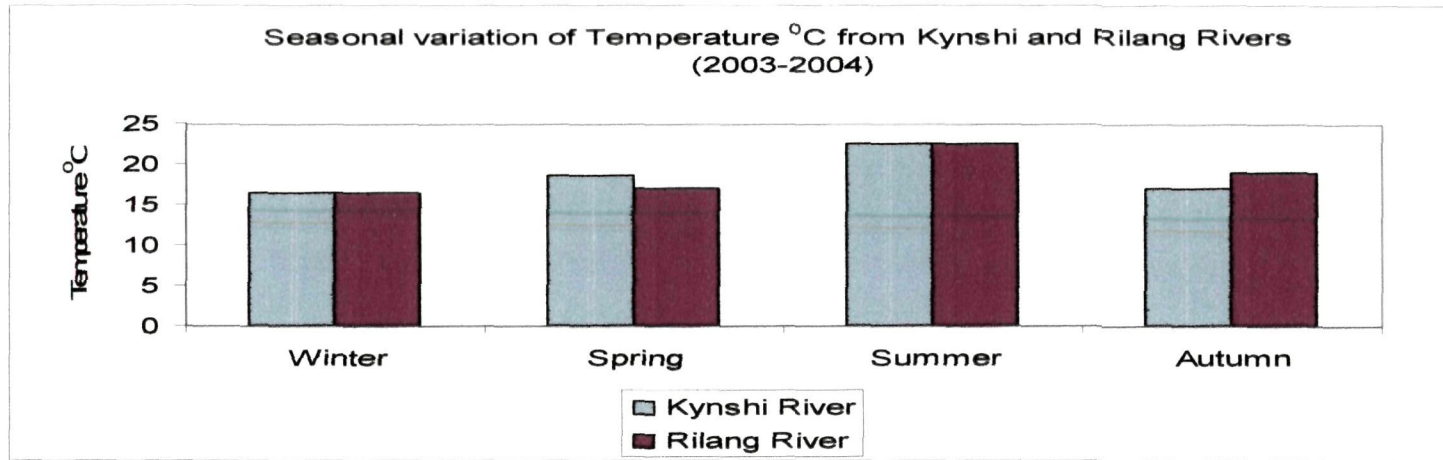


Fig: 5.7. Seasonal variation of Temperature from Kynshi and Rilang Rivers (2003-2004)

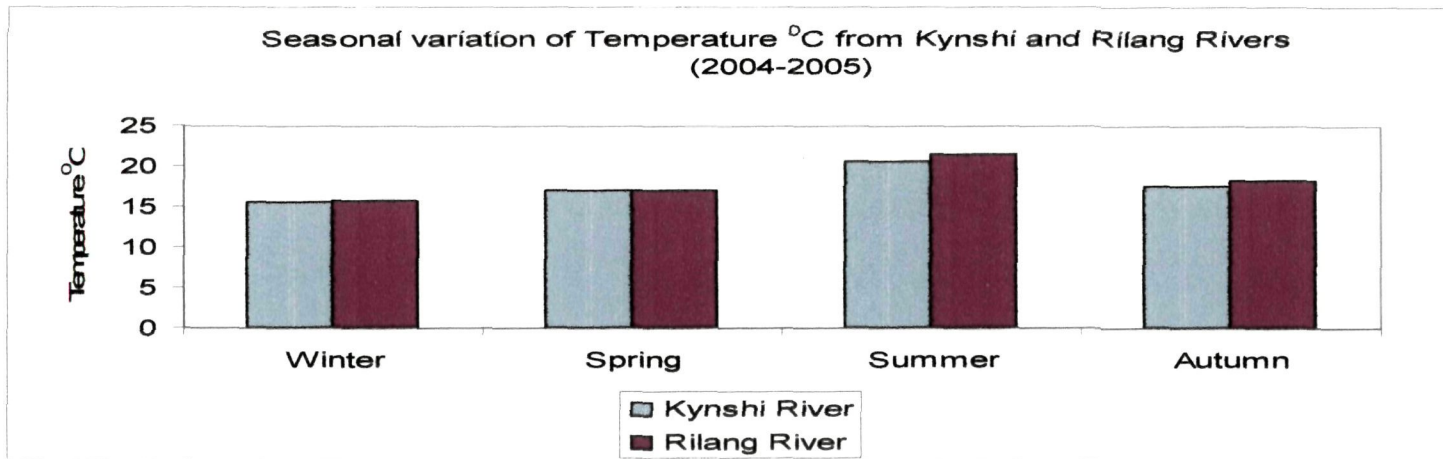


Fig: 5.8. Seasonal variation of Temperature from Kynshi and Rilang Rivers (2004-2005)

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Chapter-VI
(Bio-accumulation and Fecundity study)

Introduction

Bioaccumulation of metals can have important effects on the reproductive success of fish population and possibly the viability of their population. Metals accumulated by the adult females can be transfer to the ovaries and thereby transferred to the offspring in the egg yolk. Larvae are then exposed to the metals as they used the egg yolk during development. Such exposure can be directly toxic to eggs and larvae or cause physical deformities in larvae, which increase the rate of mortality (Lemly, 1993). In some freshwater systems, the accumulation of trace elements has led to significant decline in fish population because of its effects on reproductive success (Van Derveer and Canton, 1997; Smith *et al.*, 2003; Peters *et al.* , 1999).

Pollution is the negative feedback of the environment that affects living organisms. With increasing industrialization and discharge of effluents, heavy metals are becoming important pollutants in aquatic ecosystems (Joshi *et al.*, 2002). Heavy metals may affect organisms directly by accumulating in their bodies or indirectly by transferring to the next trophic level of the food chain (Shah and Altindag, 2005). Heavy metals accumulate in the tissues of aquatic animals and may become toxic when accumulation reaches a substantially high level (Kalay and Canli, 2000). Knowledge about the uptake, distribution, and persistence in tissues of heavy metals is well documented (Karuppaswamy, 2004). The degree of developmental detoxification mechanisms is different between young and adult organisms (Rand and Petrocelli, 1985).

Differences in rates of excretion of toxic chemicals may also be involved in age-dependent toxicity effects. However, this proposition needs to be tested with reference to fish (Kock and Bucher, 1997; Krishnamurthy and Subramanian, 1995; John and Fernandez, 1998; Anderson and Spear, 1980).

Materials and methods

The Bioaccumulation factor (B_p), is expressed as the ratio of the concentration of elements in the organism in $\mu\text{g/Kg}$ to the concentration of the element in river water in $\mu\text{g/L}$, under equilibrium conditions. This can be represented as:

$$B_p = \frac{\text{Concentration of an element in the organism } \mu\text{g/Kg}}{\text{Concentration of an element in the river water } \mu\text{g/L}}$$

The unit of bioaccumulation factor (B_p) are L/kg

Statistical Analysis: One-Way ANOVA test are used for the statistical analysis of the data.

Results and discussion

Bioaccumulation factor of all the selected elements were calculated from the data obtain from fish and water samples of Kynshi River. It is found that in the year 2003-2004 bioaccumulation factor for Fe ranges from 829-3954 l/kg, Zn (4507-9410 l/kg); Mn (152-476 l/kg); Cu (122-397 l/kg); Ni (108-137 l/kg) and Co (113-210 l/kg). During the year 2004-2005 bioaccumulation factor for Fe ranges from 1149-3850 l/kg, Zn (5349-8255 l/kg); Mn (179-611 l/kg); Cu (345-775 l/kg); Ni (62-91 l/kg) and Co (73-98 l/kg). Statistical analysis of the data shows significant variation at ($p < 0.05$) confidence level,

(Table: 6.1-6.12). The bioaccumulation factor of all the elements are in consistent with the prescribe range of International Atomic Energy Agency (IAEA, 1978).

Studies of bioaccumulation factor are conducted under natural conditions. There is a major difference in the magnitude of laboratory derived and field derived bioaccumulation factor. Laboratory derived bioaccumulation factor may be one to four orders of magnitude lower than bioaccumulation factor derived from field data. Bioaccumulation factor obtained from field data include uncertainties regarding the concentration of the trace element in water, which is never constant and may vary from non detectable levels to pulses that are very high. Many aquatic organisms are migratory and move in and out of the study area. Both these factors contribute to uncertainties about the assumptions that the bioaccumulation factor is representative of equilibrium conditions (Bangera and Patel, 1984). Bioaccumulation factor of all the elements were also calculated from the data obtain from fish and water samples of Rilang River. It is found that in the year 2003-2004 bioaccumulation factor for Fe ranges from 602-2018 l/kg, Zn (3680-6467 l/kg); Mn (250-520 l/kg); Cu (229-479 l/kg); Ni (57-102 l/kg) and Co (104-155 l/kg). During the year 2004-2005 bioaccumulation factor for Fe ranges from 768-2999 l/kg, Zn (3386-6155 l/kg); Mn (294-701 l/kg); Cu (308-516 l/kg); Ni (53-77 l/kg) and Co (122-172 l/kg). Statistical analysis of the data shows significant variation at ($p < 0.05$) confidence level, (Table: 6.13-6.24). The bioaccumulation factor of all the elements from Rilang River concur with the prescribe range of International Atomic Energy Agency (IAEA, 1978).

In general it is observed that there is a significant variation in the bioaccumulation of elements in this species. Bioaccumulation begins when a chemical passes from the environment into an organism's cells. Uptake is a complex process which is still not fully understood. Scientists have learned that chemicals tend to move, or diffuse, passively from a place of high concentration to one of low concentration. The force or pressure for diffusion is called the chemical potential, and it works to move a chemical from outside to inside an organism (Martin and Fitzwater, 1988). A number of factors may increase the chemical potential of certain substances. For example, some chemicals do not mix well with water. They are called lipophilic, meaning "fat loving," or hydrophobic, meaning "water hating." In either case, they tend to move out of water and enter the cells of an organism, where there are lipophilic microenvironments (Andersen, 1997). The same factors affecting the uptake of a chemical continue to operate inside an organism, hindering a chemical's return to the outer environment. Some chemicals are attracted to certain sites, and by binding to proteins or dissolving in fats, they are temporarily stored. If uptake slows or is not continued, or if the chemical is not very tightly bound in the cell, the body can eventually eliminate the chemical (Li *et al.*, 1995).

This simplified explanation does not take into account all of the many factors that affect the ability of chemicals to be bio-accumulated. Some chemicals bind to specific sites in the body, prolonging their stay, whereas others move freely in and out. The time between uptake and eventual elimination of a chemical directly affects bioaccumulation. Chemicals that are immediately eliminated, for example, do not bio-accumulate (Conrad *et al.*, 1999). Similarly, the duration of exposure is also a factor in bioaccumulation. Most exposures to chemicals in the environment vary continually in concentration and

duration. In these cases, equilibrium is never achieved and the accumulation is less than expected (Dorschner and Phillips, 1999; Gunshin *et al.*, 1997). Bioaccumulation varies between individual organisms as well as between species. Large, fat, long-lived individuals or species with low rates of metabolism or excretion of a chemical will bioaccumulate more than small, thin, short-lived organisms. Thus, an old lake trout may bioaccumulate much more than a young bluegill in the same lake (Mount *et al.*, 1988).

Conclusion

An important process through which chemicals can affect living organisms is bioaccumulation. Bioaccumulation means an increase in the concentration of trace elements in fishes over time, compared to the elements concentration in the environment. element accumulate in fishes any time they are taken up and stored faster than they are broken down (metabolized) or excreted. Understanding the dynamic process of bioaccumulation is very important in protecting human beings and other organisms from the adverse effects of elemental exposure, and it has become a critical consideration in the regulation of chemicals.

Bioaccumulation begins when an element passes from the environment into an organism, uptake is a complex process which is still not fully understood. Scientists have observed that elements tend to move, or diffuse, passively from a place of high concentration to low concentration. The force or pressure for diffusion is called the chemical potential, and it works to move from outside to inside an organism. A number of factors may increase the chemical potential of certain element.

Tables for Bio-accumulation Factor of trace elements in whole body of *Garra lamta* from Kynshi River (December 2003–November 2004) with Range, Mean and Standard Deviation, in comparison with Range prescribed by IAEA: TRS-247.

Table: 6.1. Seasonal variation in Bio-accumulation factor (Bp) Fe

Seasons	Mean± SD (Bp) (l/kg)	Range(l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(3954±268 ^a)	(829-3954)	(300-30000)
Spring	(2710±720 ^a)		
Summer	(1128±770 ^a)		
Autumn	(829±660 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 281.4$). ^aMean±Standard Deviation, n=3

Table: 6.2. Seasonal variation of Bio-accumulation factor (Bp) of Zn

Seasons	Mean±SD (Bp) (l/kg)	Range(l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(7172±884 ^a)	(4507-9410)	(500-10000)
Spring	(9410±316 ^a)		
Summer	(4507±298 ^a)		
Autumn	(4809±575 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 48.39$). ^aMean±Standard Deviation, n=3

Table: 6.3. Seasonal variation of Bio-accumulation factor (Bp) of Mn

Seasons	Mean±SD (Bp) (l/kg)	Range(l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(152±28 ^a)	(152-476)	(70-1000)
Spring	(436±64 ^a)		
Summer	(398±46 ^a)		
Autumn	(476±37 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 31.13$). ^aMean±Standard Deviation, n=3

Table: 6.4. Seasonal variation of Bio-accumulation factor (Bp) of Cu

Seasons	Mean±SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(243±47 ^a)	(122-397)	(110-650)
Spring	(122±22 ^a)		
Summer	(340±50 ^a)		
Autumn	(397±20 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 31.35$). ^aMean±Standard Deviation, n=3

Table: 6.5. Seasonal variation of Bio-accumulation factor (Bp) of Ni

Seasons	Mean±SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(131±50 ^a)	(108-137)	(50-1000)
Spring	(137±50 ^a)		
Summer	(115±30 ^a)		
Autumn	(108±20 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 52.80$). ^aMean±Standard Deviation, n=3

Table: 6.6. Seasonal variation of Bio-accumulation factor (Bp) of Co

Seasons	Mean±SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(210±0.18 ^a)	(113-210)	(100-1000)
Spring	(145±8.00 ^a)		
Summer	(113±3.00 ^a)		
Autumn	(152±6.00 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 46.71$). ^aMean±Standard Deviation, n=3

Tables for Bio-accumulation Factor of trace elements in whole body of *Garra lamta* from Kynshi River (December 2004-November 2005) with Range, Mean and Standard Deviation, in comparison with Range prescribed by IAEA: TRS-247.

Table: 6.7. Seasonal variation of Bio-accumulation factor (Bp) of Fe

Seasons	Mean ±SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(2176±450 ^a)	(1149-3850)	(300-30000)
Spring	(3850±490 ^a)		
Summer	(2136±770 ^a)		
Autumn	(1149±390 ^a)		

(ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 10.74$). ^aMean±Standard Deviation, n=3

Table: 6.8. Seasonal variation of Bio-accumulation factor (Bp) of Zn

Seasons	Mean ±SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(6712±588 ^a)	(5349-8255)	(500-10000)
Spring	(5722±578 ^a)		
Summer	(5349±269 ^a)		
Autumn	(8255±881 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 13.24$). ^aMean±Standard Deviation, n=3

Table: 6.9. Seasonal variation of Bio-accumulation factor (Bp) of Mn

Seasons	Mean ±SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(179±27.00 ^a)	(179-611)	(70-1000)
Spring	(473±76.00 ^a)		
Summer	(327±27.00 ^a)		
Autumn	(611±46.00 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 48.48$). ^aMean±Standard Deviation, n=3

Table: 6.10. Seasonal variation of Bio-accumulation factor (Bp) of Cu

Seasons	Mean±SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(775±22 ^a)	(345-775)	(110-650)
Spring	(592±22 ^a)		
Summer	(345±22 ^a)		
Autumn	(422±22 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 149.5$). ^aMean±Standard Deviation, n=3

Table: 6.11. Seasonal variation of Bio-accumulation factor (Bp) of Ni

Seasons	Mean±SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(91±3.0 ^a)	(62-91)	(50-1000)
Spring	(62±3.0 ^a)		
Summer	(66±3.0 ^a)		
Autumn	(68±3.0 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 13.16$). ^aMean±Standard Deviation, n=3

Table: 6.12. Variation of Bio-accumulation factor (Bp) of Co

Seasons	Mean±SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(98±8.0 ^a)	(73-98)	(100-1000)
Spring	(86±6.0 ^a)		
Summer	(73±5.0 ^a)		
Autumn	(80±3.0 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 10.60$). ^aMean±Standard Deviation, n=3

Tables for Bio-accumulation Factor of trace elements in whole body of *Garra lamta* from Rilang River (December 2003-November 2004) with Range, Mean and Standard Deviation, in comparison with Range prescribed by IAEA: TRS-247.

Table: 6.13. Seasonal variation in Bio-accumulation factor (Bp) of Fe

Seasons	Mean± SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(2018±73 ^a)	(602-2018)	(300-30000)
Spring	(1543±63 ^a)		
Summer	(1215±23 ^a)		
Autumn	(602±14 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 424.8$). ^aMean±Standard Deviation, n=3

Table: 6.14. Seasonal variation of Bio-accumulation factor (Bp) of Zn

Seasons	Mean± SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(3680±414 ^a)	(3680-6467)	(500-10000)
Spring	(4604±348 ^a)		
Summer	(3861±422 ^a)		
Autumn	(6467±855 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 10.94$). ^aMean±Standard Deviation, n=3

Table: 6.15. Seasonal variation of Bio-accumulation factor (Bp) of Mn

Seasons	Mean± SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(250±18 ^a)	(250-528)	(70-1000)
Spring	(431±39 ^a)		
Summer	(471±32 ^a)		
Autumn	(528±23 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 6.034$). ^aMean±Standard Deviation, n=3

Table: 6.16. Seasonal variation of Bio-accumulation factor (Bp) of Cu

Seasons	Mean± SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(258±13 ^a)	(229-479)	(110-650)
Spring	(229±17 ^a)		
Summer	(479±12 ^a)		
Autumn	(415±14 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 549.1$). ^aMean±Standard Deviation, n=3

Table: 6.17. Seasonal variation of Bio-accumulation factor (Bp) of Ni

Seasons	Mean± SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(69±4 ^a)	(57-102)	(50-1000)
Spring	(97±4 ^a)		
Summer	(102±2 ^a)		
Autumn	(57±4 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 111.7$). ^aMean±Standard Deviation, n=3

Table: 6.18. Seasonal variation of Bio-accumulation factor (Bp) of Co

Seasons	Mean± SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(155±17 ^a)	(104-155)	(100-1000)
Spring	(105±3 ^a)		
Summer	(104±4 ^a)		
Autumn	(149±13 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 18.93$). ^aMean±Standard Deviation, n=3

Tables for Bio-accumulation Factor of trace elements in whole body of *Garra lamta* from Rilang River (December 2004-November 2005) with Range, Mean and Standard Deviation, in comparison with Range prescribed by IAEA: TRS-247.

Table: 6.19. Seasonal variation of Bio-accumulation factor (Bp) of Fe

Seasons	Mean± SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(1118±28 ^a)	(768-2999)	(300-30000)
Spring	(2999±436 ^a)		
Summer	(1463±215 ^a)		
Autumn	(768±116 ^a)		

(ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 416.0$). ^aMean±Standard Deviation, n=3

Table: 6.20. Seasonal variation of Bio-accumulation factor (Bp) of Zn

Seasons	Mean± SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(5799±385 ^a)	(3386-6155)	(500-10000)
Spring	(3386±319 ^a)		
Summer	(3645±112 ^a)		
Autumn	(6155±447 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 40.80$). ^aMean±Standard Deviation, n=3

Table: 6.21. Seasonal variation of Bio-accumulation factor (Bp) of Mn

Seasons	Mean± SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(294±21 ^a)	(701-554)	(70-1000)
Spring	(554±34 ^a)		
Summer	(437±41 ^a)		
Autumn	(701±78 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 38.20$). ^aMean±Standard Deviation, n=3

Table: 6.22. Seasonal variation of Bio-accumulation factor (Bp) of Cu

Seasons	Mean± SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(368±15 ^a)	(308-516)	(110-650)
Spring	(516±16 ^a)		
Summer	(308±12 ^a)		
Autumn	(330±16 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 203.8$). ^aMean±Standard Deviation, n=3

Table: 6.23. Seasonal variation of Bio-accumulation factor (Bp) of Ni

Seasons	Mean± SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(77±14 ^a)	(53-77)	(50-1000)
Spring	(53±9 ^a)		
Summer	(68±8 ^a)		
Autumn	(53±9 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 7.29$). ^aMean±Standard Deviation, n=3

Table: 6.24. Variation of Bio-accumulation factor (Bp) of Co

Seasons	Mean± SD (Bp) (l/kg)	Range (l/kg)	Range (IAEA: TRS-247) (l/kg)
Winter	(172±22 ^a)	(122-172)	(100-1000)
Spring	(162±21 ^a)		
Summer	(122±11 ^a)		
Autumn	(123±14 ^a)		

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 6.04$). ^aMean±Standard Deviation, n=3

Introduction

Studies on the reproductive biology of *Garra lamta* in the river of West Khasi Hills are rare. Studies on fish fecundity are important to evaluate the reproductive potential of the species, allowing inferences about the behavior of these populations (Bagenal, 1966). The present work aims to contribute to the knowledge of the reproductive biology of the fresh water fish of commonly available in West Khasi Hills, District, Meghalaya, by determining the fecundity and its relationship to total length, and gonad weight (Nelson, 1994). Annual fecundity is used as a measure of reproductive output in fishery population models and life history studies. Accurate annual fecundity estimates require identifying oocytes to be spawned in the current spawning season. Collection date for samples is important. If samples are collected too early in oocyte development, some from reserve oocytes, and fecundity will be underestimated (Macer, 1974; Anokhina, 1963).

Materials and methods

The gravimetric method is currently the most common method used to estimate fecundity. It is based on the relation between ovary weight and oocyte density in the ovary. This method can be used to estimate total fecundity (Hunter and Goldberg, 1990; Hunter, *et al.*, 1989) Using this method, fecundity (F) is determined as the product of gonad weight and oocyte density. oocyte density is the number of oocytes per gram of the ovarian tissue, and it is determined by counting of oocytes in a weight sample of ovarian tissue.

The collected specimens were brought to the laboratory. They were firstly cleaned, measured, and weighed, the ovaries of fish were removed very carefully and preserved in 5% formalin. The preserve ovaries were weighed and then samples from anterior, middle and posterior regions of each lobe were weighed accurately. The numbers of mature and maturing eggs were then found out with the help of a needle and magnifying glass. Gravimetric method (Islam and Talbot, 1968; Evans, 1969) was followed for determining the fecundity of fish.

Statistical Analysis: One-Way ANOVA test are used for the statistical analysis of the data.

Results and Discussion

Investigation on the fecundity of *Garra lamta* from Kynshi river was carried out from March 2004 to November 2004 and also from March 2005 to November 2005. Fecundity was determined at different length, and weight of different individual fishes. In the year 2004 it is found that at different length ranges from 10.65-14.20 cm of fish shows different fecundity, and significant highest means fecundity was found 7855 (7755-7955) from 12.20-13.85 cm length ranges of fish. Statistical analysis of the data shows significant variation ($p < 0.05$), (Table: 6.13-6.15). During the year 2005 it is found that at different length ranges from 10.50-14.90 cm of fish shows different fecundity, and significant highest means fecundity was found 8611 (8411-8811) from 12.00-14.90 cm length ranges of fish. This study stated that the fecundity of fish increased with the increase in size. Statistical analysis of the data shows significant variation, ($p < 0.05$) during pre-monsoon and monsoon period, whereas during post-monsoon period it shows no significant variation ($p < 0.05$; $F = 0.449$), (Table: 6.18). The variation in the fecundity estimation could be due to different environmental conditions in

which the fish populations live. The fecundity also varied with the seasons, climatic conditions and environmental habitat, nutritional status and genetic potential (Bromage *et al.*, 1992).

Studies on the fecundity of *Garra lamta* from Rilang River in the year 2004 it is found that at different length ranges from 11.00-13.80 cm of fish shows different fecundity, and significant highest means fecundity was found 8502 (7857-8625) from 12.00-13.80 cm length ranges of fish. Statistical analysis of the data shows significant variation ($p < 0.05$) during pre-monsoon, monsoon and post monsoon period, (Table: 6.19-6.21). During the year 2005 it is found that at different length ranges from 11.20-13.95 cm of fish shows different fecundity, and significant highest means fecundity was found 8654 (7810-8995) from 12.10-13.95 cm length ranges of fish. This study also stated that the fecundity of fish increased with the increase in size. Statistical analysis shows no significant variation ($p < 0.05$) during pre-monsoon period where $F=1.91$, whereas during monsoon period it shows significant variation ($p < 0.05$; $F=8.02$), during post monsoon period it shows no significant variation ($p < 0.05$; $F=0.38$), (Table: 6.22-6.24). The fecundity increased with the increasing length and weight of the fish. The results of the present study are very similar to those obtained by previous workers (Kabir *et al.*, 1998) in *Gadusia chapra*, and Narejo, (2002) in *Monopterusuchia* and *M. armatus*.

Studies on the fecundity of fish have traditionally focused on growth and survival of the early life stages. In contrast, the relationship between population fecundity (total number of maturing oocytes found in all females) and recruitment has received little attention. This may have been caused by the difficulty in finding relationships between spawning stock biomass and recruitment. However, in some recent studies (Marshall *et al.*, 1998), the population

fecundity has been calculated based on knowledge about the spawning stock composition and how fecundity relates to fish length. This approach has established stronger relationships between population fecundity and recruitment (Marshall *et al.*, 1998). The condition of fish in some populations is also known to have considerable year-to-year variation (Cardinale and Arrhenius, 2000; Lloret and Ratz, 2000). Fecundity data are in some cases also used for spawning stock biomass estimation (Bannister *et al.*, 1981).

There are a number of factors which influence fecundity, it may be increased due to the reduction of the passive feeding period which may be due to decrease in the reserved of yolk in the egg. Environmental factors such as light, temperature, running water, pH and physico-chemical quality of the water bodies are also responsible for fish fecundity. Nutritional requirement and nutritive qualities or diet also effect fish fecundity. The fecundity is closely related with length and weight, in many fishes the somatic weight changes significantly towards spawning due to nutrient flow from somatic tissue to ovarian tissue. Therefore, the relation between fecundity and weight will differ as breeding season approaches.

Marked differences in fecundity among species often reflect different reproductive strategies (Pitcher and Hart, 1982; Wootton, 1984; Helfman *et al.*, 1997). Within a given species, fecundity may vary as a result of different adaptations to environmental habitats (Witthames *et al.*, 1995). Even within a stock, fecundity is known to vary annually, undergo long term changes (Hordwood *et al.*, 1986; Rijnsdorp, 1991; Kjesbu *et al.*, 1998) and has been shown to be proportional to fish size. Larger fish produce more eggs, both in absolute and relative terms to body mass, for a given size, females in better condition exhibit higher fecundity. Fish size and condition, are thus key parameters to properly assess fecundity at the

population level. In heavily exploited populations, large old fish will be eliminated more rapidly because they are exposed to size-selective fishing mortality. In this situation, population fecundity not only declines as a consequence of the reduced abundance of the spawners, but also due to the disproportionate reduction in large highly fecund males.

Fecundity may vary among individuals, changes in environmental factors such as temperature, may affect fish condition by influencing fish behavior and metabolism, as well as food availability. Declines in fecundity due to reduced condition can be reflecting in a lower number of oocytes that develop in a given season. In extreme cases, low condition can induce reproductive failure and lead to skipped spawning seasons (Bell *et al.*, 1992; Livingstone *et al.*, 1997). Fecundity can also be affected by environmental pollution, Potential fecundity is strongly influenced by female size, trade-off between egg size and egg number, reproductive strategy and spawning pattern of the species. While size of oocytes will have a direct influence on maximum number of hydrated oocytes that can be produced in one time, reproductive strategy and spawning pattern will determine the possible number of eggs that can be produced in the spawning season. Species with indeterminate fecundity where potential annual fecundity is not fixed before the onset of spawning will have the capacity to produce more eggs than species with determinate fecundity where new vitellogenic oocytes are not produced during the spawning season.

Conclusion

A clear knowledge of fecundity plays a significant role to evaluate the commercial potentialities of fish stock and also be used to assess the abundance and reproductive potential of the spawning stock. Now a days the knowledge of fecundity has been applied for detecting

the different populations of the same species of fish in different location. *Garra lamta* is an important fish in the study area and some parts of West Khasi Hills Meghalaya, it is found almost through the year with peak during the rainy season, (June-August). In addition to sex ratio and proportion of mature individuals, fecundity is one of the most important determinants of a stock's reproductive potential. In conclusion, no single method could be provided to estimate the annual egg production of the variety of fish species. The material describe here provides an overview of available methods including their strengths and weaknesses. For each attempt to quantify fecundity and total egg production, a careful review of the reproductive biology of the respective species is necessary in order to determine which method can successfully be applied.

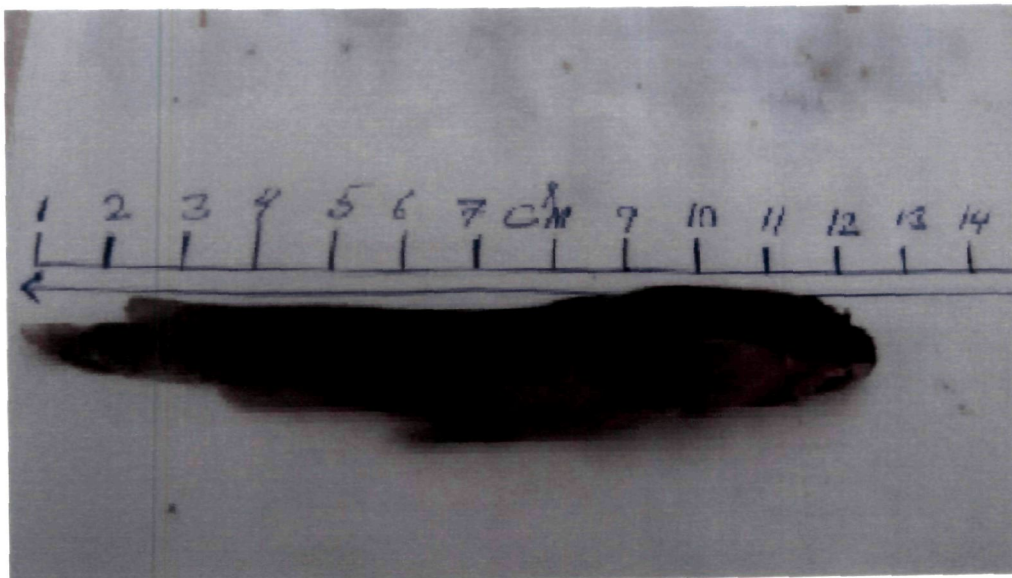


Fig: 6.1. Lateral view of *Garra lamta*

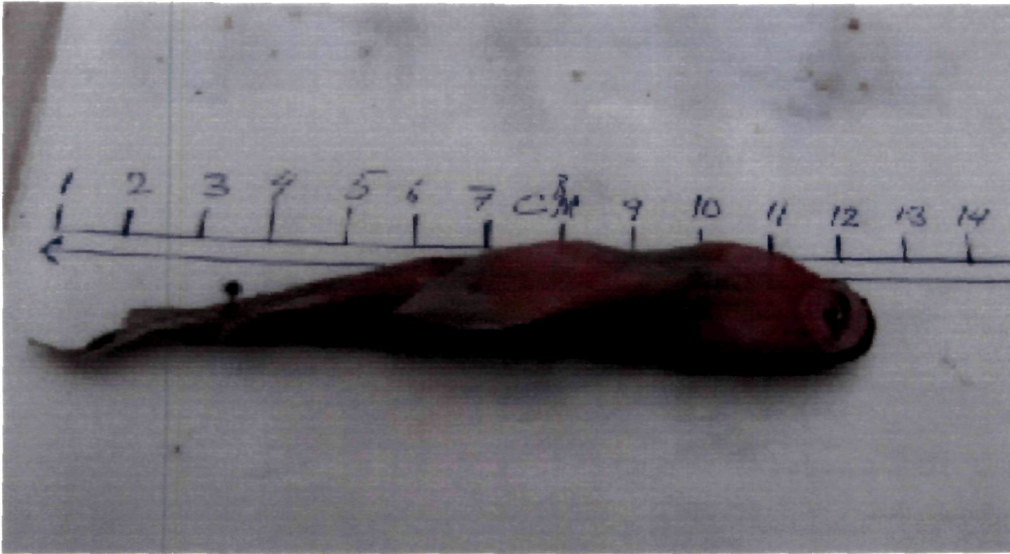


Fig: 6.2. Ventral view of *Garra lamta*



Fig: 6.3a. *Garra lamta* eggs



Fig: 6.3b. *Garra lamta* eggs

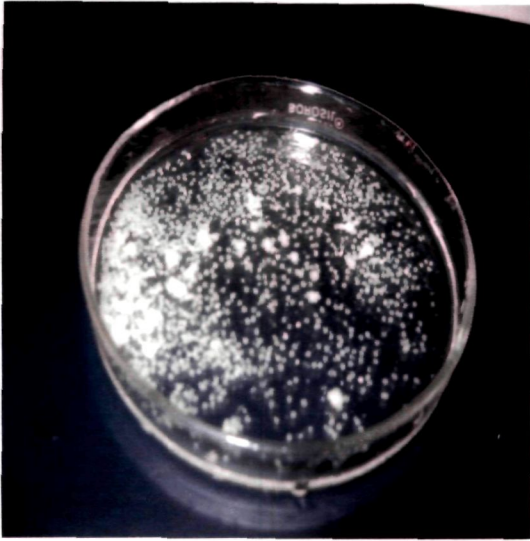


Fig: 6.3c. *Garra lamta* eggs



Fig: 6.4. *Garra lamta*

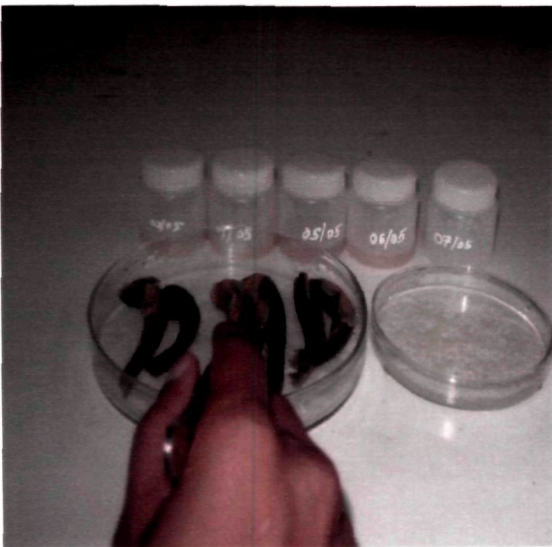


Fig: 6.3d. *Garra lamta* eggs



Fig: 6.3e. *Garra lamta* eggs

Table: (6.25-6.27). Fecundity of *Garra lamta* from Kynshi River (March 2004 – November 2004)

Table: 6.25

Months	Season	Range of Ovary Wt. (g)	Range of Fish Length (cm)	Fecundity Range	Mean Fecundity ± SD
Mar	Pre-Monsoon period	(2.80-3.60)	(10.65-12.00)	(3018-4320)	(3955 ±628)
Apr		(2.95-4.35)	(11.00-13.20)	(3398-4410)	(4410 ±470)
May		(3.55-4.10)	(11.50-13.50)	(4332-5710)	(5045 ±577)

Significant variation, ($p < 0.05$; $F_{3,8} = 4.73$)

Table: 6.26

Months	Season	Range of Ovary Wt. (g)	Range of Fish Length (cm)	Fecundity Range	Mean Fecundity ± SD
Jun	Monsoon period	(3.10-4.15)	(12.00-13.40)	(4295-6210)	(5413 ±813)
Jul		(3.85-4.85)	(12.20-13.85)	(7755-7955)	(7855 ±125)
Aug		(2.50-3.70)	(12.35-14.20)	(7185-7585)	(7385 ±200)

Significant variation, ($p < 0.05$; $F_{3,8} = 15.75$)

Table: 6.27

Months	Season	Range of Ovary Wt. (g)	Range of Fish Length (cm)	Fecundity Range	Mean Fecundity ± SD
Sep	Post-Monsoon period	(3.25-4.60)	(11.50-12.75)	(7255-7655)	(7455 ±200)
Oct		(3.15-4.25)	(12.20-13.60)	(7728-7928)	(7828 ±100)
Nov		(3.20-4.50)	(12.40-13.25)	(6955-7912)	(7435 ±545)

Significant variation, ($p < 0.05$; $F_{3,8} = 7.50$)

Table: (6.28-6.30). Fecundity of *Garra lamta* from Kynshi River (March 2005 – November 2005)

Table: 6.28

Months	Season	Range of Ovary Wt. (g)	Range of Fish Length (cm)	Fecundity Range	Mean Fecundity ± SD
Mar	Pre-Monsoon period	(2.85-3.50)	(10.50-12.50)	(3298-4282)	(3741 ±542)
Apr		(3.30-3.60)	(11.00-13.15)	(4152-5290)	(4473 ±547)
May		(3.30-3.75)	(12.85-13.90)	(4710-5298)	(4952 ±500)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 5.294$)

Table: 6.29

Months	Season	Range of Ovary Wt. (g)	Range of Fish Length (cm)	Fecundity Range	Mean Fecundity ± SD
Jun	Monsoon period	(3.40-3.80)	(13.50-14.50)	(5111-6220)	(5432 ±527)
Jul		(3.90-4.85)	(16.00-17.50)	(7282-8821)	(8118 ±724)
Aug		(3.55-4.90)	(17.40-18.00)	(8180-8580)	(8380 ±200)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 36.87$)

Table: 6.30

Months	Season	Range of Ovary Wt. (g)	Range of Fish Length (cm)	Fecundity Range	Mean Fecundity ± SD
Sep	Post-Monsoon period	(3.60-3.85)	(17.00-18.90)	(8227-8627)	(8427 ±200)
Oct		(3.40-4.55)	(17.50-18.95)	(8212-8812)	(8512 ±300)
Nov		(3.20-4.15)	(18.20-18.85)	(8411-8811)	(8611 ±200)

ANOVA test shows no Significant variation, ($p < 0.05$; $F_{3,8} = 0.449$)

Table: (6.31-6.33). Fecundity of *Garra lamta* from Rilang River (March 2004 – November 2004)

Table: 6.31

Months	Season	Range of Ovary Wt. (g)	Range of Fish Length (cm)	Fecundity Range	Mean Fecundity \pm SD
Mar	Pre-Monsoon period	(3.70-4.10)	(11.90-12.50)	(4200-4333)	(4491 \pm 485)
Apr		(3.90-4.25)	(11.95-12.50)	(5200-5443)	(5038 \pm 561)
May		(4.40-5.50)	(11.20-12.00)	(5550-5852)	(6162 \pm 638)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 9.23$)

Table: 6.32

Months	Season	Range of Ovary Wt. (g)	Range of Fish Length (cm)	Fecundity Range	Mean Fecundity \pm SD
Jun	Monsoon period	(4.85-5.20)	(12.80-13.20)	(6710-7990)	(7075 \pm 626)
Jul		(5.11-5.97)	(12.00-13.80)	(7857-8625)	(8502 \pm 590)
Aug		(4.75-5.20)	(12.20-13.10)	(7210-8980)	(8374 \pm 828)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 5.51$)

Table: 6.33

Months	Season	Range of Ovary Wt. (g)	Range of Fish Length (cm)	Fecundity Range	Mean Fecundity \pm SD
Sep	Post-Monsoon period	(4.20-5.10)	(11.80-12.50)	(7480-8819)	(8385 \pm 570)
Oct		(4.95-5.10)	(11.00-12.00)	(7505-8717)	(8402 \pm 590)
Nov		(4.20-5.82)	(12.20-12.50)	(7410-8388)	(8422 \pm 476)

ANOVA test shows no Significant variation, ($p < 0.05$; $F_{3,8} = 6.02$)

Table: (6.34-6.36). Fecundity of *Garra lamta* from Rilang River (March 2005 – November 2005)

Table: 6.34

Months	Season	Range of Ovary Wt. (g)	Range of Fish Length (cm)	Fecundity Range	Mean Fecundity \pm SD
Mar	Pre-Monsoon period	(4.00-4.80)	(11.80-12.00)	(4280-5710)	(4630 \pm 786)
Apr		(3.95-4.40)	(11.20-12.50)	(4010-5380)	(4635 \pm 684)
May		(4.15-4.80)	(11.50-12.10)	(4380-6440)	(5612 \pm 962)

ANOVA test shows no Significant variation, ($p < 0.05$; $F_{3,8} = 1.91$)

Table: 6.35

Months	Season	Range of Ovary Wt. (g)	Range of Fish Length (cm)	Fecundity Range	Mean Fecundity \pm SD
Jun	Monsoon period	(5.10-5.80)	(12.10-13.50)	(6611-7750)	(7188 \pm 531)
Jul		(5.15-5.80)	(12.15-13.95)	(7810-8995)	(8654 \pm 569)
Aug		(4.70-5.20)	(12.20-13.75)	(7890-8970)	(8230 \pm 569)

ANOVA test shows Significant variation, ($p < 0.05$; $F_{3,8} = 8.06$)

Table: 6.36

Months	Season	Range of Ovary Wt. (g)	Range of Fish Length (cm)	Fecundity Range	Mean Fecundity \pm SD
Sep	Post-Monsoon period	(4.15-4.60)	(11.60-12.85)	(7001-8442)	(7996 \pm 670)
Oct		(3.70-4.00)	(11.70-12.80)	(7110-8980)	(7858 \pm 765)
Nov		(3.70-4.10)	(11.60-12.90)	(7890-8940)	(8187 \pm 504)

ANOVA test shows no Significant variation, ($p < 0.05$; $F_{3,8} = 0.38$)

Introduction

Gonado-somatic index has been used as an indicator of reproductive activity (Elorduy-Garay and Ramírez-Luna, 1994; Rajasilta *et al.* 1997). Its utility to detect hydrated ovaries and therefore detect reproductive period from increase in weight has been established by Hunter and Macewicz, (1985), Thus the Gonado-somatic index provides a useful estimation of spawning duration (Ceballos-Vázquez and Elorduy-Garay, 1998). Gonado-somatic index provides useful information about the annual trend in the reproductive activity of the population, the annual trend in the mean monthly values of the Gonado-somatic index is consistent with the reproductive activity.

Materials and methods

Applying the method of June, (1953) and Yuen, (1955), the relative weight or Gonado-Somatic index by using the following formula:

$$\text{Gonado-Somatic Index} = \frac{\text{Weight of ovary}}{\text{Weight of the fish}} \times 100$$

Result and Discussion

Monthly variation of GSI values of fishes is graphically represented in fig. 6.5. From the figure it is evident that GSI values are found to increase from March onwards reaching a peak in July followed by a gradual decrease up to November. Increase in GSI values of the

fishes indicate development of the gonads during March to July and a sudden drop observed in December which indicates spent stage of fish. The monthly variation in the GSI offer not only additional proof for the spawning season but also is indicative of the major phages of reproductive cycles. In this study GSI clearly shows that *Garra lamta* has a wide spawning season (March-November) in fresh water environments of West Khasi Hills District of Meghalaya.

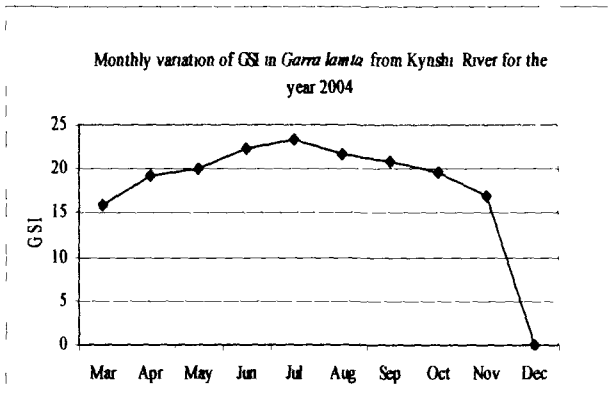


Fig: 6.5 (a).

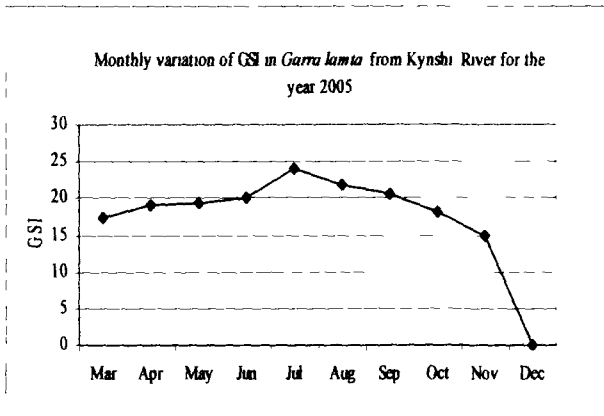


Fig: 6.5 (b)

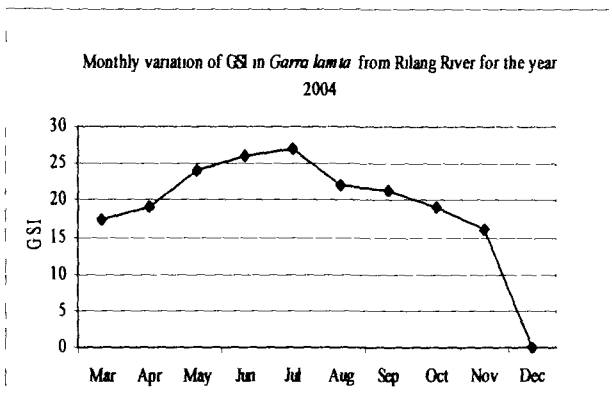


Fig: 6.5 (c)

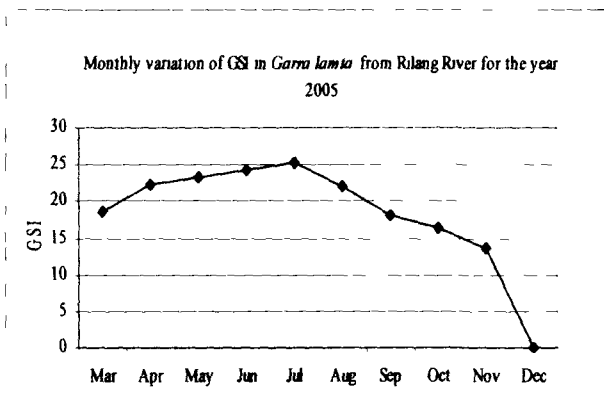


Fig: 6.5 (d)

***Fig: 6.5 a, b, c and d: Graphical representation of GSI from Kynshi and Rilang Rivers for the year 2004-2005

Correlation study between GSI and Element concentration

Correlation study between GSI value and elements concentrations was performed during the year 2004 and 2005 from data available from both the rivers. It is found that there is a significant correlation between GSI value and element concentration during the period of study from both the study sites. In the year 2004 high significant correlation ($p < 0.05$) was observed between GSI value and elements like Mn, Cu and Co from Kynshi river where 'r' value for Mn Cu and Co is 0.99. In the year 2005 high significant correlation ($p < 0.05$) were observed between GSI and element like Mn, $r = 0.99$. (Table: 6.25). Correlation study from Rilang river for the year 2004-2005, high positive correlation ($p < 0.05$) was found between GSI and element like Ni, $r = 0.99$. (Table: 6.26).

The correlation observed between GSI value and element concentration may be attributed due to the gradual increase in the concentration of elements from pre-monsoon period attaining peak concentration during the monsoon season, which is in accordance with the pattern of increasing of GSI value. correlation (often measured as a correlation coefficient) indicates the strength and direction of a *linear* relationship between two random variables (GSI and elements). That is in contrast with the usage of the term in colloquial speech, denoting any relationship, not necessarily linear. In general statistical usage, *correlation* or co-relation refers to the departure of two random variables from independence. In this broad sense there are several coefficients, measuring the degree of correlation, adapted to the nature of the data. A number of different coefficients are used for different situations. The best known is the Pearson

product-moment correlation coefficient, which is obtained by dividing the covariance of the two variables by the product of their standard deviations.

Correlation matrix between Element concentrations and GSI value giving values of Pearson's Correlation Coefficient (r).

KYN Shi RIVER

Table: 6.37

	Elements					
	Fe	Zn	Mn	Cu	Ni	Co
GSI (2004)	0.67	0.63	0.99*	0.99*	0.57	0.99*
GSI (2005)	0.95	0.90	0.99*	0.75	0.92	0.76

RILANG RIVER

Table: 6.38

	Elements					
	Fe	Zn	Mn	Cu	Ni	Co
GSI (2004)	0.83	0.98	0.60	0.72	0.99*	0.65
GSI (2005)	0.82	0.98	0.88	0.98	0.99*	0.71

Significant correlation: $p < 0.05^*$

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This study is a part of general environmental survey of the area and is therefore an attempt to provide baseline information regarding concentration of selected trace element in this species, and also the concentration of trace elements in the two rivers. This study are intended for essential elements, since trace elements currently regarded by the World Health Organization as essential for human health are iron, zinc, copper, cobalt, manganese and nickel in addition to chromium, iodine, molybdenum, silicon, boron, vanadium and selenium. The purpose of this study was to determine concentrations of selected trace elements in whole body of commonly available freshwater fish species in this region (*Garra lamta*). This study is confining to two Rivers of West Khasi Hills, (Kynshi river and Rilang river) Meghalaya North Eastern India, where there is a deposit of uranium ore. This study will serve as baseline data for comparison with the monitoring results in future.

The studies on the concentration of heavy metals in fish species as well as water bodies provide useful information for the development of surveillance programs aimed at ensuring the safety of the water bodies and minimizing human exposure. In the present study, we explored the levels of heavy metals Fe, Zn, Mn, Cu, Ni and Co in *Garra lamta* keeping in view scarcity of data on this issue. This study was designed to establish the distributions and seasonal variations of trace metals (Fe, Zn, Mn, Cu, Ni and Co), in commonly available fish species (*Garra lamta*) of the area and also to study the seasonal variation of trace elements and some of the important abiotic parameters like alkalinity,

dissolve oxygen, pH and temperature. Correlation studies of trace elements between the two aquatic ecosystems are also perform. The objective of the baseline study of an ecological assessment is to provide adequate and accurate ecological baseline information. It is found out that all the selected elements falls well below the guideline values of World Health Organization, and the area can be regarded as pristine area and it will not pose any threats to the biotic communities exists in the region.

Environmental monitoring programme is a vital process of any management plant of the development project. This help in signalling the potential problems that resulting from any proposed project and will allow for prompt implementation of effective corrective measures. The environmental monitoring will be required for the construction and operational phases. The main objective of environmental monitoring are to asses the changes in environmental conditions and to monitor the effective implementation of mitigation measures, and also to warn significant deteriorations in environmental quality for further preventive action.

Environmental assessment is described as one of the most successful policy innovations. Today it is a formal process used in more than hundred countries and organizations to help decisions makers consider the environmental consequences and proposed action. The question is whether environmental assessment can remain a relevant and effective tool responding to the demand of changing world environment.

The purpose of the study was to determine the background level of different parameters like concentration of elements in whole body of *Garra lamta*, total concentration of elements from the two rivers, total alkalinity, dissolved oxygen, pH and temperature. The baseline study was designed to describe chemical and physical impacts on these two fresh water bodies. In this study it is also observed that there is a highly positive correlation between the two study sites.

The study gives a clear knowledge about the fecundity of *Garra lamta* collected from the two rivers. Now a days the knowledge of fecundity has been applied for detecting the different populations of the same species of fish in different location. *Garra lamta* is an important fish in the study area and some parts of West Khasi Hills, Meghalaya. It is found almost through the year with peak during the rainy season, (June-August). In conclusion, no single method could be provided to estimate the annual egg production of the variety of fish species. The material describe here provides an overview of available methods including their strengths and weaknesses. The monthly variation in the GSI offer not only additional proof for the spawning season but also is indicative of the major phages of reproductive cycles. In this study GSI clearly shows that *Garra lamta* has a wide spawning season (March-November) in fresh water environments of West Khasi Hills District of Meghalaya.

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Publications Lists

1. **P.S. Iongwai**, B. Kharbuli, S.A.War, D.T. Khating and S.K. Jha. (2009). Study on seasonal variation of Fe, Zn, Mn, Cu, Ni and Co in *Garra lamta* (fresh water fish) from Kynshi River of West Khasi Hills District, Meghalaya, India. 96th *Indian Science Congress*. Shillong. pp: 198-199.
2. **P. S. Iongwai**, B. Kharbuli, D. T. Khathing, D. G. Marbaniang, S. Myrthong, A. Rabha and K. Rabha. (2007). Study on the Seasonal Variation of Major and Trace Elements in *Garra lamta* (Hamilton) from Kynshi River of West Khasi Hills, Meghalaya. *Proceedings of DAE-BRNS National Symposium on Limnology*. Udaipur. pp: 138-139.
3. **P. S. Iongwai**, B. Kharbuli, D. T. Khathing, D. G. Marbaniang, S. A. War and S. K. Jha (2007). Evaluation of Trace Elemental (Cu, Mn, Ni, Cr and Co) Variability in *Neolissocheilus hexagonolepis* from Kynshi River of West Khasi Hills, Meghalaya, India. *Proceedings of Fifteen National Symposium on Environment*. Coimbatore. pp: 276-280.
4. **P.S. Iongwai**, B. Kharbuli, D.T. Khathing, S. A. War and S.K. Jha. (2007). Assessment of Trace Elements Concentration in Two Aquatic Ecosystems of West Khasi Hills, Meghalaya, India. 'Twelve World Lake Conference, 2007'. Jaipur. India.
5. D. T. Khathing, B. Myrboh, P.Nongkynrih, S.A. War, D. G. Marbaniang and **P. S. Iongwai**. (2005). Baseline Environmental Survey of Proposed Uranium Mining Projects of Domiasiat, Meghalaya. *Proceedings of Fourteenth National Symposium on Environment. Environmental Geochemistry*. Vol. 8, No. 1 & 2, pp: 96-103.
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