PHYSIOCHEMICAL STUDIES AND TRACE ELEMENTAL ANALYSIS OF SPRING AND WELL WATER IN AND AROUND THE MAJOR DISTRICTS OF NAGALAND

THESIS SUBMITTED TO THE SCHOOL OF SCIENCE
NAGALAND UNIVERSITY
FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN CHEMISTRY

T. TIAKABA JAMIR
Registration No.224/2005
DEPARTMENT OF CHEMISTRY
NAGALAND UNIVERSITY
Hqrs: Lumami

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Ph.D. THESIS

Topic: PHYSIOCHEMICAL STUDIES AND TRACE ELEMENTAL ANALYSIS OF SPRING AND WELL WATER IN AND AROUND THE MAJOR DISTRICTS OF NAGALAND

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NAGALAND UNIVERSITY
MAY 2009

Dedicated to my family members

DECLARATION

I, Shri T.Tiakaba Jamir, hereby declare that the matter embodied in this thesis is the result of investigations carried out by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else and that the thesis has not been submitted by me for any research degree in any other university/Institute.

This is being submitted to the Nagaland University for the degree of Doctor of Philosophy in Chemistry.

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I have a great pleasure in forwarding the thesis entitled "*Physiochemical Studies and Trace Elemental Analysis of Spring and Well Water in and around the Major Districts of Nagaland*" submitted by my student Mr. T. Tiakaba Jamir for the degree of Doctor of Philosophy(Science) in Chemistry of Nagaland University.

I certify that:

The candidate was registered as a Research Scholar for Ph. D. (Sc.) degree in Chemistry in Nagaland University under my direct supervision.

The candidate has fulfilled all the necessary conditions for submission of the thesis for Ph. D. (Sc.) degree under Nagaland University. The contents of the thesis are the original work of T. Tiakaba Jamir and this thesis or any other part of it has not been submitted elsewhere for any degree.

R. K. Bhubon Singh

Dated: May 7, 2009

(Dr. R. K. Bhubon Singh)
Supervisor

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I am also grateful to my wife Aren for being a rock during the long tedious years of my study. My sincere gratitude goes to my entire family members for their continued support and prayers. I am eternally grateful to them.

Kohima: 7th May 2009

7/05/09

(T.TIAKABA JAMIR)

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1.1 Introduction: Water

Water is one of the most essential factors for the survival of the human race, and so its health and well being is closely related to the quality of water. However, the water available is being contaminated and polluted due to rapid urbanization, population explosion and industrialization etc. Water is also likely to become critically scarce in the coming decade due to continuous increase in its demand, rapid expansion of economy and rapid increase in population. In view of this significant uncertainty there is therefore an urgent need to monitor, analyze and study the quality of water sources, availability in the state and to find out and suggest remedies if any, for the benefit of the people of Nagaland at large.

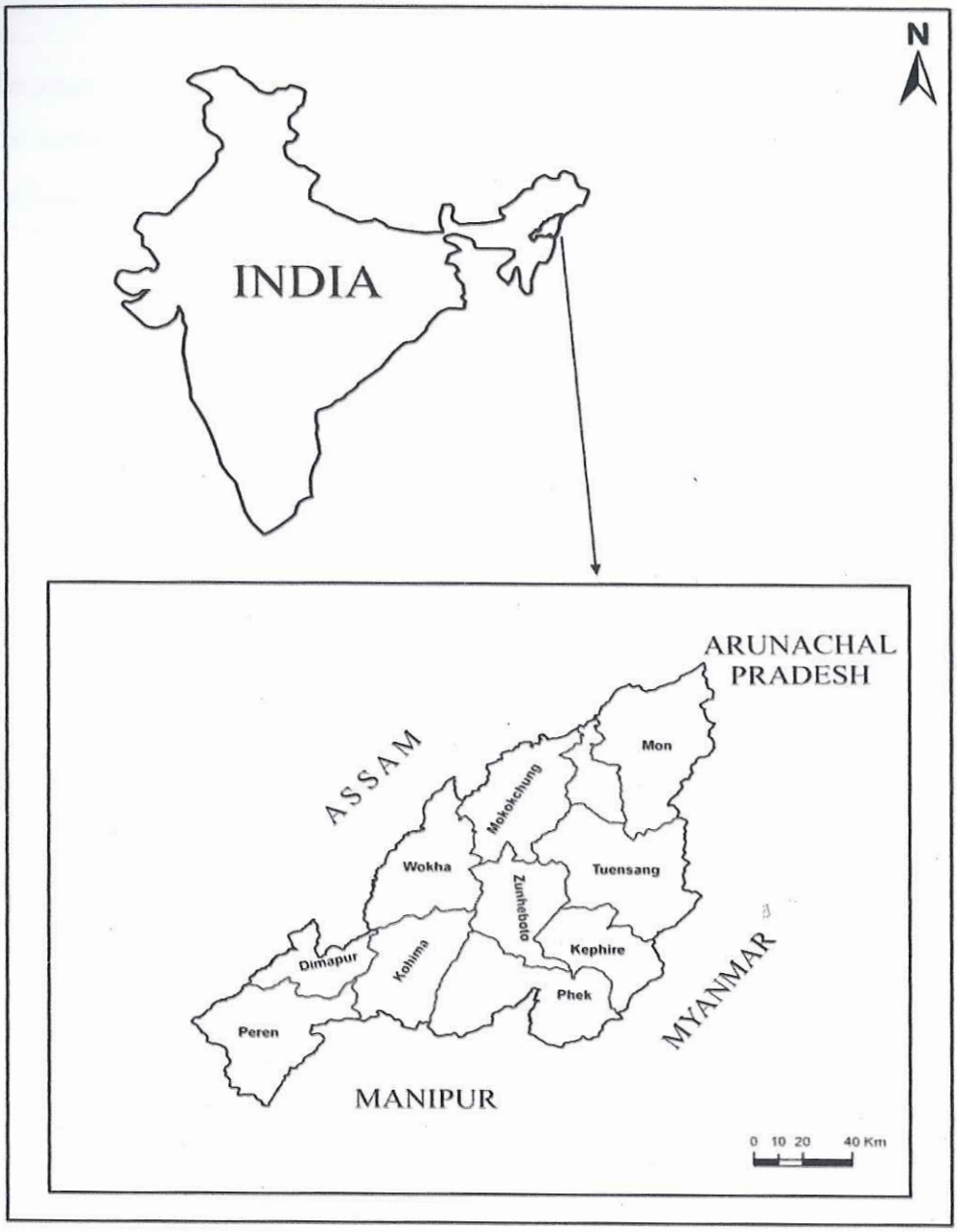
According to the National water policy in Planning and Operation, the priorities related to water-based issues should be broadly classified as under:

(i) Drinking water
(ii) Irrigation
(iii) Hydropower
(iv) Ecology
(v) Agro-industries and non-agricultural industries.

It should, therefore, be ensured that people have primary access to safe drinking water that adheres to the prescribed guidelines given by World Health Organization (WHO) for quality drinking water.

1.2 Nagaland State: A brief description

Nagaland, the sixteenth state of the Indian Union is situated in the North-East region of India. Statehood came as a result of political agreement in 1963 and constitutional protection was specially provided for Nagaland under Article 371 A of the Indian constitution to safeguard the culture, traditions and way of life of the Nagas. The state of Nagaland lies between $25^0 60^0$ and $27^0 40^0$ latitude North of Equator and the Longitudinal lines $93^0 20'$E and $95^0 15'$ E having an area of 16578 sq km[1]. The total population of Nagaland as per 2001 census is 19.88 lakhs, with a population density of 120 per sq km. The state consists of 11 major districts and is inhabited by 16 major tribes, each with its own distinct language, custom and traditions[2]. The state is predominantly rural with 82.26% of the population living in villages. The main economic activity is agriculture, engaging 68.03% of the working force. Besides agriculture, people are also engaged in rearing of livestock, weaving, black smithy and handicrafts. The state does not have any major industry and almost the entire urban population depends upon government services for employment and livelihood. The state is experiencing fast rate of growth in the urban centers. In 1981, the urban population of the state was 1.2 lakhs, which increased to 3.5 lakhs in 2001. In the absence of urban development plans, this momentum of growth has created problems especially in Kohima, Dimapur and Mokokchung district as compared to the other urban centers of the state. This trend of in-migration of people to the urban centers from rural areas and smaller urban centers in the state as well as influx of illegal immigrants has caused serious impact not only on the ecosystem but also the human environment. This is major is a cause for concern and as a result, the state is today struggling to cope with haphazard growth of main urban centers, traffic and congestion, pollution, inadequacy of water and sanitation facilities, sewerage systems, drainage and solid waste management.



NAGALAND MAP

1.3 Water resources and availability in Nagaland

The state of Nagaland has no dearth of water resources. The predominant source of water is surface water in rivers, streams, ponds and natural springs and subsurface water occurring as ground water. Also the annual average rainfall of Nagaland is about 2500 mm [2].The high rainfall in this region generally gives rise to abundant water supplies particularly during the monsoon session (May – Sept) and due to this high rainfall rate, the water availability in surface and ground water are also in abundance and are put to domestic, agricultural and industrial uses. However due to lack of proper management, destruction of the catchments areas and headwaters through shifting cultivation etc. the water resources in the State are facing a silent death.

Water and Land resources degradation in Nagaland is both man-made as well as a natural phenomenon. Rapid population growth, improper land use, absence of land use policy, and the growing demands of increasing urbanization are exerting adverse pressure on the environment and on the natural resources of the state. Loss of vegetation due to deforestation, shifting cultivation/jhum, unplanned agricultural practices and encroachment into forest land for agriculture and settlements, forest fire, over grazing is some important factors contributing to the degradation of Land and water resources in Nagaland.

Apart from this, pollution from untreated sewage, industrial effluent, agricultural run-off etc. are also contaminating the water sources. The demand for water continues to escalate particularly in urban areas, thereby emphasizing the need to focus on activities for harnessing rain water and recharge of ground water.

1.4 Literature review on quality of surface and ground water of India with special reference to North Eastern Region of India

In the North Eastern region of India, natural springs and the dug well are primarily the only viable means of fulfilling the needs of fresh water for present population. In hilly areas, most of the drinking water is harnessed from rivers, ponds and natural springs. Many springs are reportedly becoming seasonal and dying. While in valleys, most of the drinking water is harnessed from ground water through dug and tube wells. And since most of the peoples in north east region of India use water from tube wells for drinking, cooking and agricultural purpose and this way the toxic elements especially arsenic enters the food chain. This could cause chronic arsenic toxicity in the course of time resulting in arsenical skin lesion and dermities in the initial stage and cancer and death if patients are exposed to high concentration over prolonged periods.

It is reported that thousand of underground water resources in north east India are unfit for consumption due to high toxic contamination. A staggering 32,077 water sources have been contaminated with naturally occurring inorganic minerals like arsenic, iron and fluoride. A study conducted by NERIWALM revealed that 28,181 water sources located in Assam have been contaminated with these inorganic materials, followed by 2931 in Tripura, 566 in Arunachal Pradesh, 124 in Meghalaya, 76 in Sikkim, 37 in Manipur and 26 in Mizoram. In Nagaland alone, 136 water sources under studies were reported to be contaminated with excess inorganic materials [4]. It was reported that the arsenic levels in Assam, Manipur, Tripura and Arunachal Pradesh were above 300 ppb (parts per billion).According to World Health Organization (WHO) consumption of water contaminated with arsenic levels of over 50 ppb can cause skin lesion and cancer. Thus the presence of these excess inorganic materials especially arsenic found in ground water could pose a serious health risks for the people of these regions.

It was also reported that a large number of people dwelling in the deltaic regions of West Bengal use water with arsenic in excess of the prescribed suitable limits for human health and since at present the primary source of drinking water in rural and urban areas are the private domestic tube wells, tapping water shallow aquifers (50-200 ft), data from different sources from eastern India indicate high Arsenic content in water from such shallow aquifers [5]. However, in many areas the deeper (>500 ft) aquifers too show arsenic content above the permissible limit 0.05 mg/L according to Indian standards. Ever since the first detection of arsenic-induced hypo pigmentation and Keratosis in the 1980s, campaigns are being organized to create general awareness and several measures have been deployed to provide safe drinking water. The most common of these in rural West Bengal are the community based online fitters that work on the principle of arsenic removal by absorption, oxidation and precipitation by Fe, Al oxides hydroxides [5]. In the early eighties, arsenic contamination of ground water was detected in six eastern districts of West Bengal, India, the concentration ranged from 0.06 mg/L. to 1.86 mg/L for in excess of World Health Organization drinking water provisional guidelines value of 0.01 mg/L. It is estimated that over 1, 50,000 people were affected by arsenic and are suffering from arsenical dermatosis (black spots, eruptions, and even cracking of skin). Similar problems have also become apparent in Bangladesh in areas bordering India, but their geographical extent is yet to be defined [6].

High concentration of arsenic in ground water has been reported from the West Bengal Delta plains in West Bengal and Bangladesh [7-11]. Symptoms of arsenicosis are primarily manifested in the forms of different types of skin diseases like skin lesions, hyperkeratosis, melanosis etc.[12] Arsenic is also the cause of various carcinogenic manifestations.

The distribution of arsenic in carbonaceous materials like coal and bituminous materials across the four north eastern states of India including Nagaland has been reported. It is also reported the distribution of total arsenic content in carbonaceous matter, Assam (lignitic): 80.0- 207, Assam (sub-bituminous): 44.0 – 78, Nagaland

(lignitic): 56.0-68.0, Meghalaya (sub-bituminous): 106.0-238.0 and Arunachal Pradesh (graphitic): 39.0-50.0 mg/Kg and warned for immediate continuous monitoring of the situation as it may cause a serious public-health concern to these heavily populated developing states. Although, increasing arsenic levels in ground water have been reported in neighboring Bangladesh and it (As) has been occurring in various natural systems. However, there is no detailed reports and studies available about the presence of As and other toxic elements in the North Eastern region of India particularly, Nagaland, even though the history of geological solution of sedimentary basins geographically located in West Bengal, and neighboring Bangladesh is similar to the north eastern states of India. Our attention has been drawn to the recent havoc of increasing arsenic level in the ground water in West Bengal, covering an area of 37.493 sq. km lying close to the metropolitan city of Kolkata [13, 14] with a maximum concentration being 3.7 mg/L (permissible limit of potable ground water is only 0.05 mg/L) which has caused a serious public health concern, particularly eastern part of India. Since the occurrence of such toxic elements are geologically related in the sedimentary environment with dominant carbonaceous materials and bears significant environmental consequences.

Reports on arsenic concentration in groundwater in north eastern India also revealed that the arsenic concentration in many water sources exceeds the WHO permissible limit. It is reported that, the arsenic concentration in Jorhat, Lakhimpur, Nalbari and Nagaon districts of Assam was found to be in the ranges of 112-601μg/l. In Manipur, very high arsenic concentration in ranges 798-986 μg/l was reported from Kakching block area of Thoubal district. While in Arunachal Pradesh, six districts were to have high arsenic concentration in the ranges 618 μg/l. In Tripura, part of West Tripura, North Tripura and Dhalai districts have arsenic concentration in between 65-444 μg/l. In Nagaland several locations viz. Tzudikong, Tuli in Mokokchung and Naginimora, Namtula and its adjoining areas in Mon districts is reported to have high arsenic consideration above the permissible limits [15, 16]. A trace of arsenic was also reported from Wokha and Zunheboto districts of Nagaland [15].

The presence of fluoride in ground water has also been reported in most of the states of India. Severe contamination of fluoride in ground water of Karbi Anglong and Nagaon districts of Assam and its manifestations in the form of fluorosis have been reported [17-19]. Subsequently, reports about fluoride in ground water in certain parts of Guwahati, Assam have created confusion among the residents of concerned areas in the city [20]. Ground water quality in Guwahati has been studied with special reference to the presence of fluoride. The Brahamaputra river in the North, hills in the East and South, and alluvial soil to the West surround the city. Fluoride above the guideline values of World Health Organization (maximum permissible limit is 1.0 mg/L) has been found in ground water of the Eastern and Southern plains of the Guwahati city, Assam. It was also reported that fluoride contents showed positive correlation with Na^+, K^+, total alkalinity and deep of source, and negative correlations with Mg^{2+}, Ca^{2+} and total hardness [21].

Study of fluoride concentration in ground water and its impact on human health in east Imphal district of Manipur have also been reported. It revealed that, out of the analysis of 60 samples collected from dug well and bore wells showed fluoride concentration in six ground water samples which were within the permissible limits of (minimum acceptable concentration 0.7 mg/L) whereas at 30 ground water samples fluoride concentration was below desirable limits and at 24 ground water samples it was below detectable limit[18]. It was recommended to maintain fluoride concentration within permissible limits, so as to prevent tooth decay, carries and other adverse effects on human beings [22, 23].

It was also reported that the concentration of iron in North eastern region is relatively high and almost all the states of this region contain iron above the permissible level in drinking water. Among the states the maximum amount of iron was observed in Assam, Meghalaya, Mizoram, Nagaland and Tripura [15].

Reports have also been made of the presence of trace heavy metals in the surface water of Pachin river in Itanagar, Arunachal Pradesh above the permissible level. The trace metals like Fe and Co were amongst the highest concentration of the rivers, while these metals and Cr, Mn, Cu and Se each exceeded the world average value[24]. These results clearly indicate that rivers draining pristine areas can be significantly modified by human activities and consequently, these must be monitored to ensure that useable water supplies meet the prescribed safety standards [23, 24]. The trace element analysis of ground water samples of Karond area of Bhopal also revealed that the concentration of iron and manganese at certain locations exceeded the desirable limits prescribed for drinking water. The maximum concentration recorded for iron and manganese was 1.32 and 0.348 mg/l respectively. The presence of Fe and Mn above desirable limit affects taste and appearance of water supply [25].

Analyses of trace elements in surface water in and around the uranium bearing area of Wahkyn uranium deposits West Khasi Hills district, Meghalaya is also reported, and that despite the close proximity of high grade uranium deposit, elemental concentrations such as Fe, Cu, Zn, Ni, Cr, Pb, Cd, Mo, V, As, Se, Fe & Al were all within the WHO limits of potable water[26].

A review on the reports of quality of surface and ground water in some parts of India also revealed large scale contamination of surface and ground water. Reports on the assessment of the extent of pollution with reference to fluctuation in CO_2 an pH and its impact on potable water quality of river Irai of Chandrapur district covering an area of nearly 25 kilometers that witnessed tremendous growth in the industrial field shows the minimum pH value of 6.3 mg/L during winter season and maximum of 8.93 mg/L in summer. The pH shows general decline from upstream to downstream. CO_2 was found to maximum in summer reaching up to 55.44 mg/l and reduced to a minimum of 2.28 mg/L during rainy season[27].

Surface and ground water pollution in some of the coal mining and industrial areas of Jharia coalfield Dhanbad was also reported and the result showed that surface and groundwater at many sites of the areas is contaminated and some parameters such as TDS, Fe, NO_3, hardness and conductivity exceeds the stipulated quality standards. It was reported that water quality at some of the locations of the area is found deteriorating and need immediate attention to restore the water quality in the region [28]. Also report on study of water quality assessment of river Gomti in Lucknow City indicated the increase in the river's BOD, COD, alkalinity, chlorides, total hardness, conductivity, total solids but the dissolved oxygen (DO) and pH decreased which signify that the water is significantly polluted and is not fit for most beneficial uses except for irrigation, fish culture and industrial cooling .With regards to heavy metals, except Iron, all heavy metals such as lead, copper, zinc and chromium were reported to be well within the permissible limits [29].

Analytical study of heavy metals of industrial effluents at Jaipur, Rajasthan also revealed the presence of heavy metals in waste water in the range Cu (0.0-1.0 mg/l), Fe (0.1-0.4 mg/l), Mn (0.0-0.4 mg/l), Ni (0.01-0.07 mg/l) and Zn (0.68-60.84 mg/l). Copper, Iron, Manganese and Zinc were found above the prescribed limits. The Heavy metals contamination has been recognized as a major environmental concern and since heavy metals are not biodegradable, there need to develop a remediation technique, which should be efficient, economical and rapidly deployable in a wide range of settings [30].

The physiochemical nature and its potential environmental impact of seepage water at various levels of coal mine of Pathakhera, Madhya Pradesh reports that the physiochemical characteristics such as water temperature, pH, dissolved oxygen, alkalinity, carbonate, bi-carbonate, total hardness, calcium hardness, magnesium hardness chloride and chemical oxygen demand varied in between the range of 15-36^{0}c, 6.0-7.2, 5.2-6.6 mg/l, 36-52 mg/l, 18-36mg/l, 12-24 mg/l, 330-404 mg/l, 233.1-352.8 mg/l 11.245-24.034 mg/l, 46-71 mg/l and 608-752 mg/l respectively [31].

Reports on groundwater contamination in different parts of Delhi also revealed severely affected area and wide range of contaminants such as fluoride(<1-16.mg/L) and nitrate (<20-1600mg/L).It is reported that during the last decade, fluoride and nitrate levels in groundwater increased by 2-6 times. Due to public ignorance to environmental considerations and lack of provisional basic services, indiscriminate disposal of increasing anthropogenic wastes on land, into river and unlined drains, and unplanned application of agro-chemicals and improperly treated sewage water continued, resulting in excessive accumulation of pollutants on the land surface. Leaching of contaminants from landfills as well as seepage from canals/river and drains caused severe degradation of the groundwater at many places exceeding the WHO prescribed maximum limits in drinking water. It is also reported that in Punjab and Haryana, groundwater nitrate levels ranges from <25 mg/L to 1800 mg/L and fluoride level 1.5-45.8 mg/L. And in the absence of known major geological sources of fluoride and nitrate, excessive application of agro-chemicals and discharges from steel, aluminum, brick and tile industries and disposal of crop residues is a major cause of pollution. Trace to excessive amounts of heavy metals, such as, Zn (3-41 µg/L), Cu (5-182 µg/L), Fe (279-1067 µg/L), Mn (<1-76 µg/L), Pb (31-6221 µg/L), Ni (<1-105 µg/L) and Cd (<1-202 µg/L) is also reported to have found in the groundwater at some places of Delhi near industrial sites, Haryana and Uttar Pradesh [32].

Regarding the physiochemical characteristics of drinking water of all eight north eastern states of India, it was reported that the pH of water samples from six North Eastern state viz Assam, Meghalaya, Mizoram, Sikkim, Nagaland and Tripura showed a slightly acidic reaction. Whereas the pH of drinking water of Arunachal Pradesh and Manipur was reported to be within the permissible level as per BIS guidelines[15]. The dissolved oxygen DO value in drinking water of seven North Eastern States was reported to have above the permissible level whereas in Nagaland state the DO value was found below the permissible limit in the ranges of 0.1-3.7mg/L [15]. With regard to TDS in

drinking water it was reported that the maximum TDS was observed in Assam and Tripura states while rest of the NE states contain lesser TDS [15].

A Physiochemical characteristic of surface water samples of Loktak Lake in Manipur has also been reported. The study reflected the average mean value of the parameters pH, conductivity and TDS has the mean value of 7.03, 599.62 μ mho cm^2 and 1180.5 mg/l respectively. In chemical parameters, hardness and alkalinity respectively has the mean of 31.62 mg/l and 121.87 mg/l. Among the cationic groups calcium has 8.015 mg/l, Magnesium 304 mg/l, Sodium 6.75 mg/l and Potassium 2.25 mg/l; Phosphate, sulphate and chloride have 0.0198 mg/l, 0.058 mg/l and 12.6 mg/l respectively and lastly total nitrogen has the mean of 40.6 mg/l. The study also revealed the dominance of Calcium in cationic and Chloride in anionic components and among the nutrient phosphate was found to be the lowest as compared to nitrogen [33].

1.5 Statement of the problem of surface and ground water in Nagaland

There is very little information available on the quality of surface water and ground water in the State as it has not been studied extensively and monitoring of water bodies in the state is a very recent phenomenon and taken up on a very limited basis. In terms of quality, the surface water of the state is unprotected from untreated industrial effluents and wastewater, runoff pollution from chemical fertilizers and pesticides. No sewage treatment facilities exist in the State. The state has no proper drainage system, thus overflow of septic tanks and cesspools is very common particularly in urban areas. The contaminated water often flow into the open drains which then enter the natural streams and rivers further polluting water sources.

The neglect of water sources has created a potential of all water bodies becoming polluted and toxic in the near future. The increasing pollution of water bodies constitutes the biggest threat to the public health. Since spring and well water are the main sources of drinking water for the people of Nagaland the larger mass of public are chiefly dependant on the surface and ground water for potable water particularly in the rural areas. Although the Public Health Engineering Department (PHED) and in some urban areas, the private agencies supply drinking water to the general public, the quality of these drinking water cannot be ascertained as there is no reports of studies undertaken. Work carried out on water quality control in Nagaland by the government organizations are yet to be known. However, very recently a few reports have come up that in certain districts like Mokokchung and Mon districts of Nagaland the arsenic content is beyond the permissible limits [15, 16] of World Health Organization (WHO) guidelines and Bureau of Indian standards (BIS). Also report on groundwater quality of few sites in Dimapur show relatively high values of electrical conductivity up to 895 μmho/cm indicating higher degree of mineralization and high concentration of Iron in the groundwater which is much higher than the national recommended limits and needs further investigation[3].

These alarming reports of the water quality in this region and continuous consumption of this water has a potential of posing serious health hazard to the local population. In the light of these reports, it is necessary to conduct an extensive and exhaustive study of the water quality of surface and ground water of Nagaland and to identify the sites of contamination so as to ensure that the people of the state have free access to safe drinking water.

1.6 Aim and objectives of the research work

The aim of this research work is to ascertain the quality of drinking water of Nagaland as people of this state know very little of what is going on underground. The public ought to understand the severity of the condition of our rivers and address the situation before our water sources become parched with effluence.

This research work emphases the physiochemical characteristics and trace heavy metal elemental analysis of drinking water from spring and well water in and around the major towns of Nagaland. The work mainly concentrates in the areas where there is no data/report in the literature. In fact, so far there is very little or no standard report on physiochemical characteristic and toxic trace heavy metal elemental analysis of spring and well water of Nagaland and therefore, the aim of this research work is that the public is made aware of the quality of their water sources and some remedial measures undertaken for the benefit of the health and economy of the people of the state.

The following are the main aim and objectives of the work:

1. Collection of spring and well water samples from different districts of Nagaland.
2. Analysis of physiochemical properties like colour, Temperature, electrical conductivity, Total Dissolved Solids, Dissolved Oxygen, Biological Oxygen Demand, Chemical Oxygen Demand, Total Hardness of Calcium and Magnesium and comparative study of the results with respect to World Health Organization and Bureau of Indian Standards.
3. Determination of trace elements like Pb, Cd, As, Ag, Mn, Hg, Zn, Fe, Ni, Ca, Mg etc by atomic absorption spectroscopy.
4. Element wise and district wise comparative study of the analytical results with respect to World Health Organization and Bureau of Indian Standards and
5. Concluding discussions and suggestions on the above findings

CHAPTER -2
MATERIALS AND METHODS

2.1 Introduction

The chemical composition of water sample generally consists of four types: soluble minerals dissolved gases, soluble organic compounds and suspended materials.

The list of soluble minerals is extensive. However the common cation in soluble minerals is Calcium, Magnesium and Sodium coupled with the anions bicarbonate, sulfate and chloride.

The dissolved gas found in water supplies consists of air (oxygen and nitrogen), carbon dioxide, hydrogen sulfide and methane. Surface water contains the largest amount of dissolved oxygen and lesser concentration of carbon dioxide and hydrogen sulfide. Methane, carbon dioxide and hydrogen sulfide may occur in significant concentration in ground water.

The soluble organic compound in water supplies is growing daily due to rapid industrial synthesis. The organic pollutants entering water supplies by way of sewage and industrial discharge are surfactants (synthetic detergents), phenol, lignin and tannin.

The suspended particles/materials arise due to decaying vegetation of swampy areas which exist largely in the form of colloidal suspension.

The natural water samples often contain a solid phase in addition to the normal liquid phase. The solid phase called turbidity, range from a colloidal particles size to coarse sand, and may be of inorganic or organic origin. The inorganic constituents may consist of clay, silt, calcium carbonate, silica, hydrated iron oxide, alumina and other

related minerals. The organic constituents may be of composed of microorganisms and finely divided animals and vegetables substances of various degrees of complexity.

The removal of the soluble phases from water samples is important for a reliable result. The soluble phases was removed by a commonly approached method such as filtration, centrifugation etc.

2.2 Location of sampling sites.

Keeping in mind the over all objective of the study and the sample to be collected, all possible types of representations of the area, the locations of all the potable water sources were noted by mapping the area using a topo sheet on 1:50000 scale. A large number of spring and well water sources were identified and samples collected seasonally in summer (June-August) and winter (January-March) starting from January 2005 to July 2008 for four continuous years. Samples were collected seasonally from 20-30 locations each for every season from seven districts (Kohima, Dimapur, Mokokchung, Tuensang, Wokha, Lumami under Zunheboto, Tseminyu and Ungma) covering mainly the urban areas of Nagaland.

Map showing the locations of water sources collected for analyses

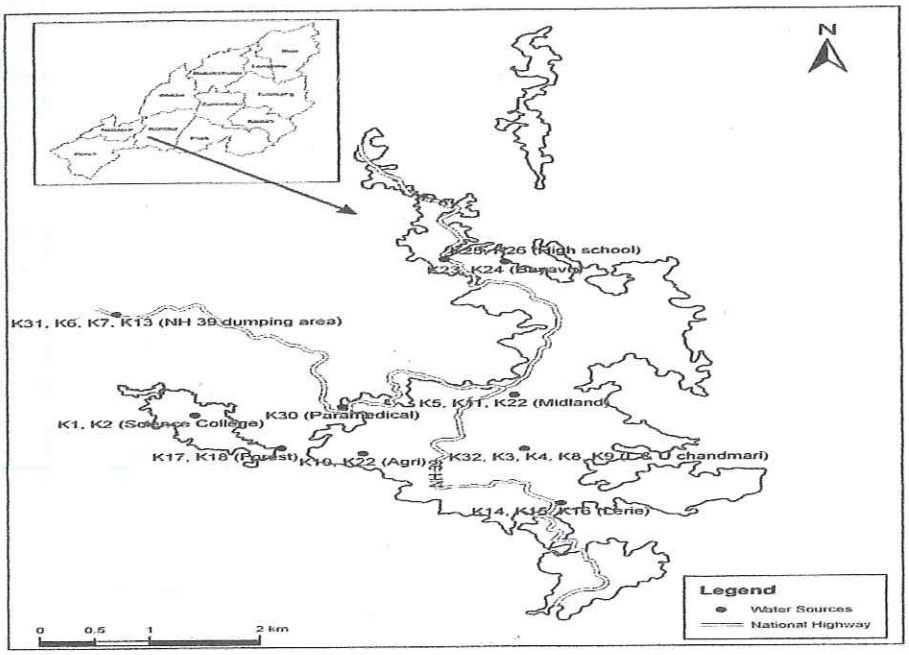


fig 1. Kohima

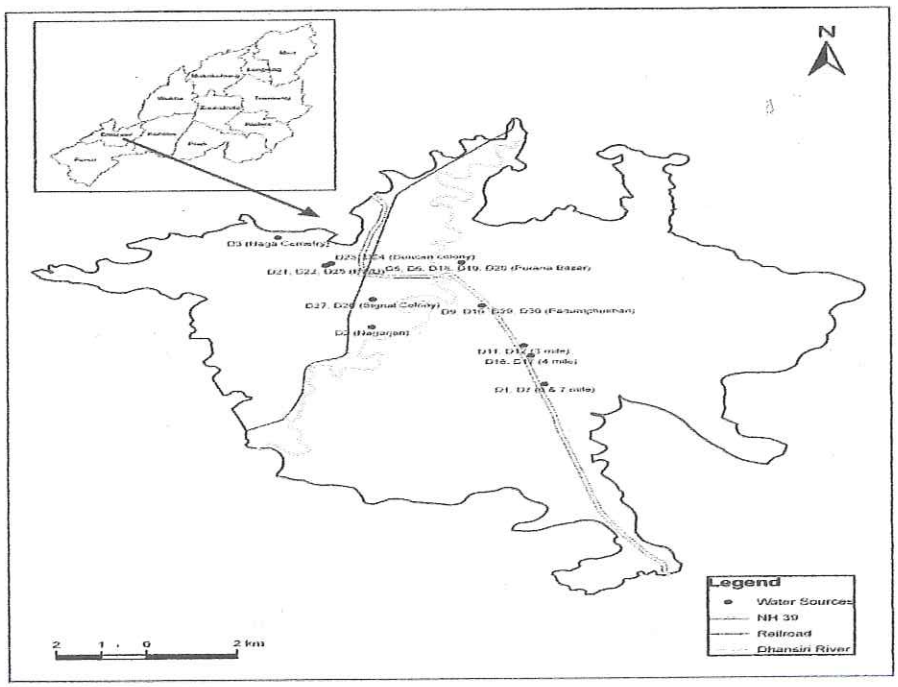


fig.2. Dimapur

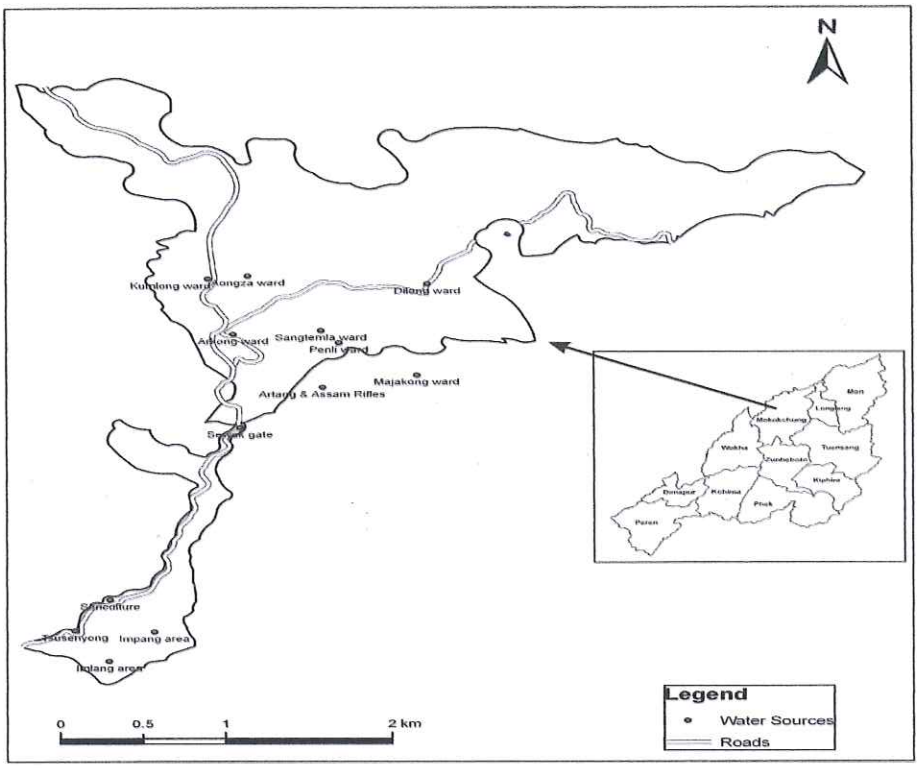


fig 3. Mokokchung

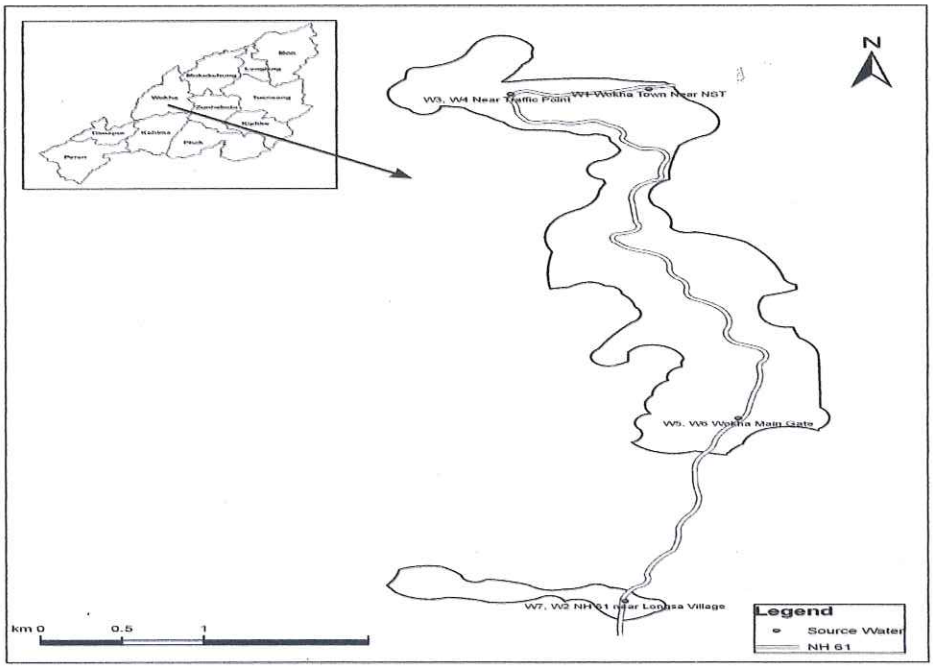


fig 4. Wokha

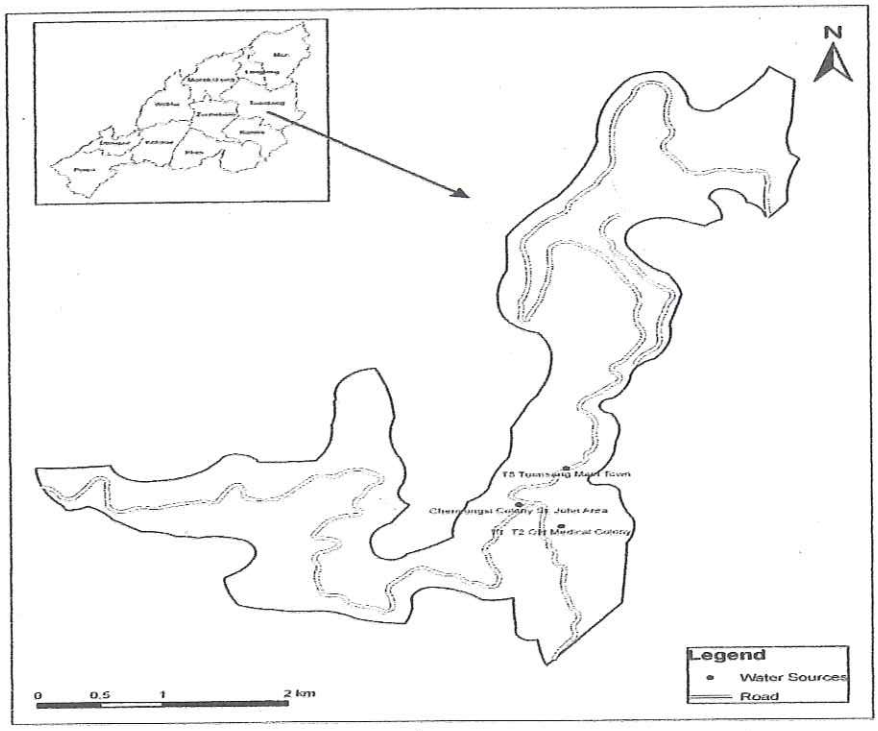


fig 5. Tuensang

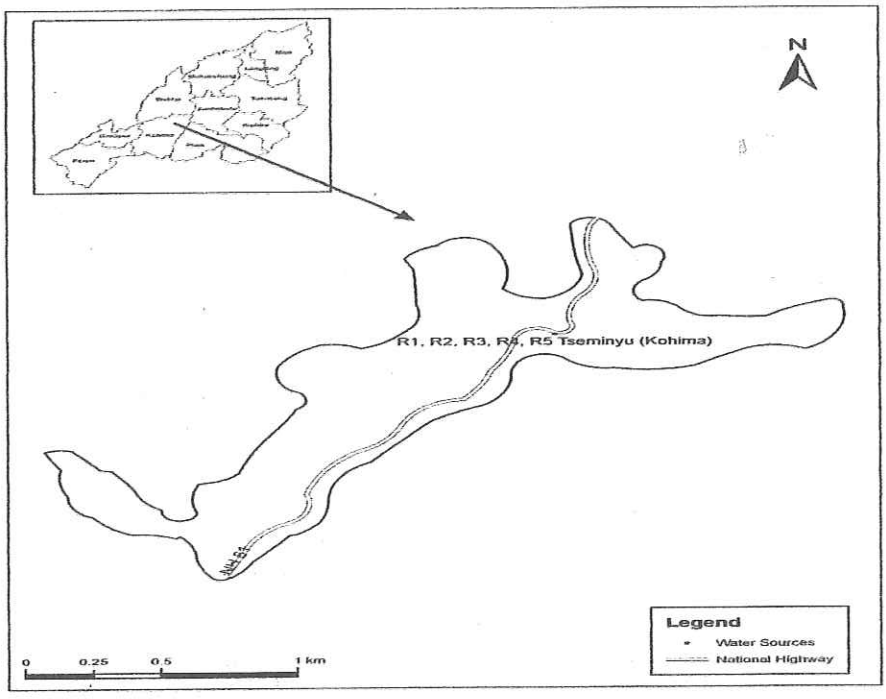


fig 6. Tseminyu sub-division under Kohima

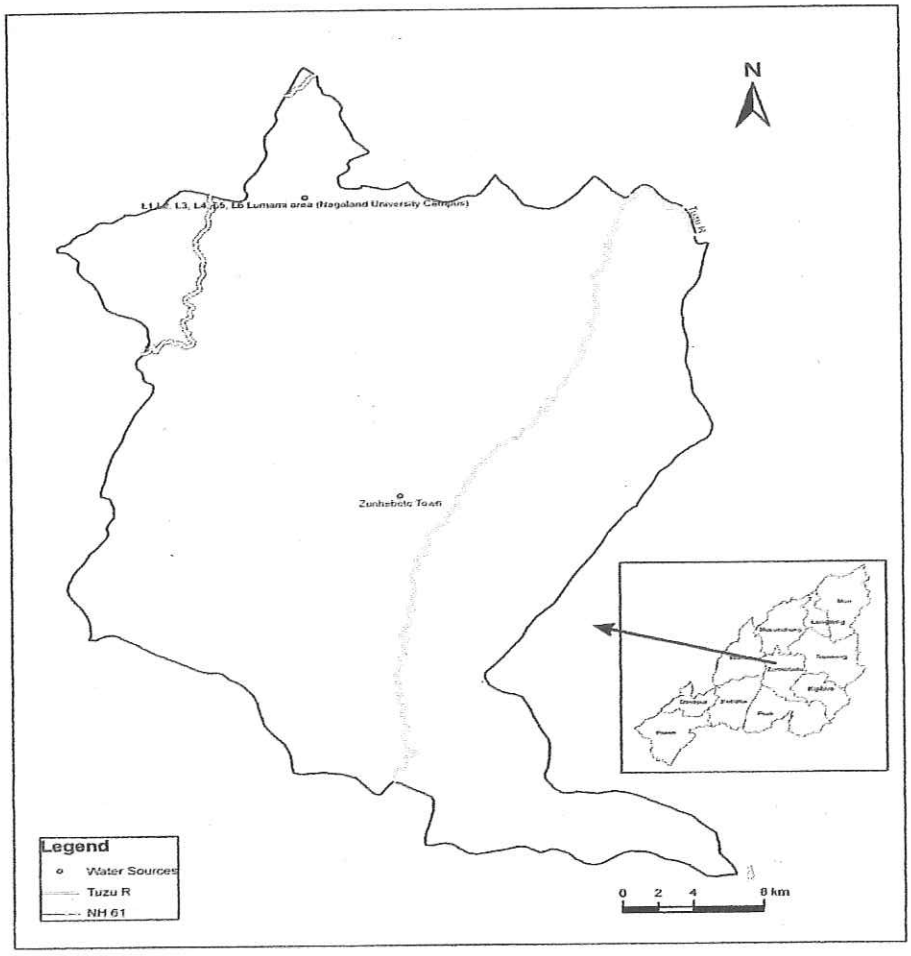


fig 7. Lumami under Zunheboto

2.3 Methodology for collection of spring and well water samples.

2.3.1 Sampling

The collection of the sample is an important phase of the analyses. A sensible collection of sample technique was observed to guarantee a sample that presents a true picture of the stream or well that is being examined.

The relevant factors for any sampling technique are (a) frequency of sample collection (b) total number of samples (c) size of each sample (d) sites of sample collection (e) method of sample collection (f) data to be collected with each sample, and (g) transportation and care of samples prior to analysis [26]. The collection of representative samples was insured by adequately flushing a service line until the water reaches a constant temperature, before actual collection was attempted. Ground water sample collection was done with prior pumping to obtain a sample that reflects the main body of water. This ensures that the composition of the sample is identical to that of the water body from which it is collected and the samples share the same physiochemical characteristics with the sampled water at the time and site of sampling. Analysis of physiochemical characteristics such as pH, conductivity, temperature, total dissolved substances and dissolved gases of water samples was collected in a clean plastic container of 1L capacity. The entire container was tightly capped and the stopper, whenever necessary was replaced in such a manner so as to entrap as little air as possible.

It was ensured that the samples for analyses of physiochemical characteristics such as pH, temp, electrical conductivity, TDS etc was determined as quickly as possible on the spot, using water quality testing kits (eutech model cyperscan, Singapore) in order

to get an accurate result. In some unavoidable cases, the samples were carefully brought to the laboratory for analysis using pH meter and conductometer.

The water samples under examination was collected seasonally (January-March) and (July-September) every year from various parts of the different districts of Nagaland for four consecutive years i.e 2005-2008.

2.3.2 Preservation of sample

There can be a change in physical and chemical composition when the time and analyses of water sample is prolonged. Some changes are -aluminum, chromium, copper, lead and zinc may be lost through adsorption or ion exchange with the walls of container. Iron and manganese may precipitate as a sediment or dissolve from the turbidity, depending on the redox potential of the sample. Sodium, silica and boron may be leached out of a glass container. Changes in the pH, alkalinity, and carbon dioxide can induce the precipitation of calcium carbonate thereby lowering the values of calcium and total hardness. Microbiological activity can change the nitrate-nitrite-ammonia balance, decrease the phenol content, and reduce sulfate to sulfide. Colour, odor and turbidity may increase, decrease or change in quality [34]. Due to these considerations the analyses of water sample was undertaken within 12-48 hour of collection. However when the analysis was to be postponed for some unstated reason beyond the stated time limits, the sample was pretreated or fixed to preserve the samples.

To preserve the dissolved oxygen balance, the sample was preserved by addition of, in quick succession a 0.7 mL conc.H_2SO_4 and 1 mL NaN_3 (2g per 100ml) well below the liquid surface and the bottle is well stoppered to prevent the access of air [34].

The trace heavy element was preserved by acidified with conc. HCl to a pH of about 3 to minimize precipitation and adsorption on the wall of the container [34].

Some pictures of water sources taken for analysis

fig 1. Precious water

fig 2. How safe is this water

fig 3. Unprotected Stream

CHAPTER-3

PHYSIOCHEMICAL PARAMETERS

3.1 Introduction

The physiochemical characteristics of representative water samples was studied by analyzing the following quality parameters such as colour, pH, electrical conductivity, TDS, dissolved oxygen, BOD, COD, total hardness, calcium and magnesium hardness of water collected seasonally i.e.(Jan-March) and (June–August) from various part of Nagaland for four consecutive years (2005-2008).

3.2 Nature, significance, principle and procedure of measurement of different parameters.

3.2.1 Colour

Water in nature is often coloured and this colour is due to the presence of various natural substances such as humus, peat materials, weeds, metallic ions like iron or manganese, sewage and industrial waste. Coloured water is not aesthetically acceptable to the general public and is also not accepted for certain uses in industries.

The colour of water is extremely pH dependant. It increases as the pH of the water is raised. In this study, Colour was measured by visual comparison of the samples.

3.2.2 Temperature

Temperature is primarily important and has a direct impact on the chemistry and biological reactions in the organism in water. The variety and distribution of aquatic organisms and other life forms greatly depend on water temperature. An increase in water temperature leads to faster rate of chemical and biological activities in water, decreases

the solubility of gases and changes the taste and odour. Anaerobic decomposition is also largely affected by temperature change. Temperature is also important in the determination of various other parameters such as pH. Electrical Conductivity, saturation level of gases and various form of alkalinity etc. Water temperature is recorded using a portable water testing kit as well as a standard centigrade thermometer in 0^0C at the site of collection.

3.2.3. pH

pH is the negative logarithm of the hydrogen ion concentration in a solution.

Mathematically $pH = -\log_{10}[H^+]$

$= \log_{10} 1/[H^+]$

pH is the measures of intensity of alkalinity and measures the hydrogen ion concentration in water. pH is one of the most characteristic features of water quality which controls the aquatic environment. All chemical and biological reactions are directly dependant on hydrogen ion concentration. The pH of water also indicates the degree of pollution. The main sources that regulate the pH in natural water are CO_2, carbonic acid, bicarbonate ion and carbonate ion. An increased carbon dioxide concentration will therefore lower pH, where as a decrease will cause it to rise. Temperature will also affect the equilibrium and the pH. In pure water, a decrease in pH of about 0.45 occurs as the temperature is raised by 25 °C. The pH of most drinking-water lies within the range 6.5 – 8.5 [35]. Under natural condition the value of pH in surface water ranges from around 5.0 to 8.6. The pH of neutral water is 7.00 at 25^0C. However significant change in pH occurs due to discharge of industrial waste, sewage and drainage etc. The effects of acids and alkalis depend on the strength of the acid or alkali and the concentration. Strong concentrated acids or alkalis are corrosive, whereas dilute and weak acids and alkalis are not corrosive. pH can affect the degree of corrosion of metals as well as disinfection efficiency. pH measurement was carried out on the spot using portable digital pH meter kits (eutech cyperscan, Singapore) with temperature compensation arrangement.

3.2.4 Electrical conductivity

Conductivity is used to measure the ability of water to conduct electric current. The conduct of electric current depends on the presence of ions as these ion transport the electric current in the solution. The conductivity increases as the concentration of ion in the solution increases. The conductivity test determines the total dissolved salt and can be made by measuring the electrical conductance of water samples.

Electrical conductivity of water samples was measured by using portable digital Conductivity kits (eutech cyperscan, Singapore) on the spot as well as in the laboratory.

3.2.5. Total dissolved solids (TDS)

TDS comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates) and small amounts of organic matter that are dissolved in water. TDS in drinking-water originate from natural sources, sewage, urban runoff and industrial wastewater. Concentrations of TDS in water vary considerably in different geological regions owing to differences in the solubility of minerals. Reliable data on possible health effects associated with the ingestion of TDS in drinking-water are not available, and no health-based guideline value is proposed. However, the presence of high levels of TDS in drinking-water (greater than 1200 mg/litre) may be objectionable to consumers. Water with extremely low concentrations of TDS may also be unacceptable because of its insipid taste [35, 36].

TDS in water samples was measured using portable digital water testing kits (eutech, cyperscan, Singapore) on the spot.

3.2.6 Dissolved oxygen (DO)

Dissolved oxygen is one of the most important parameters and reflects the physical and biological processes prevailing in the waters. Its presence is essential to maintain higher life forms of biological life in water and the effect of waste discharge is largely determined by oxygen balance of the system. It is a key factor in water pollution and waste treatment and process controls. The presence of high concentration of organic matter depletes the dissolved oxygen and thereby upsets the oxygen balance. Besides the solubility of oxygen, dissolved oxygen determination is vital for ensuring aerobic conditions in water that receives polluting matter in the form of sewage or industrial waste. In liquid waste, dissolved oxygen is the most important factor in determining whether aerobic or anaerobic organisms carry out biological change. If sufficient DO is available, aerobic organisms oxidize the waste to innumerous products. If DO is deficient, anaerobic take part in the conversion and reduce the waste often to obnoxious end products.

The principle involved in the determination of DO is that when manganous sulphate is added to the sample containing alkaline (NaOH) potassium iodide, a white precipitate of manganous hydroxide is formed which is oxidized by the presence of dissolved oxygen of the sample, to a brown coloured basic manganic oxide. On addition of sulphuric acid, the basic manganese oxide liberates iodine equivalent to that of dissolved oxygen basically present in the sample. The liberated iodine is titrated against standard sodium thiosulphate solution using starch as indicator.

Dissolved oxygen (DO) was measured by Wrinkler iodometric method using starch indicator.100 ml bottle was taken and filled with the water sample avoiding any kind of bubbling and trapping of air bubbles in the bottle after placing the stopper. A precipitate appears on addition of 1 ml each of $MnSO_4$ and alkaline KI solution well below the surface from the walls. 1-2 ml of conc. H_2SO_4 was added to dissolve the

precipitate. The whole content is then transferred in a conical flask and is then titrated against 0.025 N $Na_2S_2O_3$ solution using starch as indicator. At the end point, the initial dark blue colour changes to colourless.

3.2.7 Biological Oxygen Demand (BOD)

BOD is the amount of oxygen utilized by bacteria and other microorganisms in stabilizing the organic matter. The demand of oxygen by microorganisms is proportional to the amount of organic waste to be degraded aerobically. Thus the BOD value can be used as a measure of waste strength. Generally, the higher the BOD, the greater is the amount of oxidizable organic matter present [37]. BOD test is one of the most important tests to determine the strength of polluting power of sewage, industrial wastes, effluents and polluted water. Hence it is important in stream pollution control activities. The organic matters that exert BOD in water mostly consist of dissolved substances, volatile compounds and a mixed population of microbes. For non polluted river the BOD value should be less than 3 mg/L [38]. Clean and fairly clean river water seldom exhibits a BOD in excess of 3 mg/L. The BOD of rivers water of doubtful purity may exceed 5 mg/L; On the other hand, polluted water may have 10 mg/L or more [34]. BOD value of surface water is 3 mg/L as per BIS standard. It was suggested that a BOD level of 2.0 mg/l be accepted as the maximum permissible limit for unpolluted water.

BOD is determined immediately after the collection of samples .The same process for the determination of Dissolved Oxygen was followed but for BOD one set of sample was incubated for five days at 20^0 C, after which the DO content was again obtained. The difference in DO values indicated the amount of oxygen used up by the sample during the period and represents the five day BOD.

3.2.8 Chemical Oxygen Demand (COD)

COD is the oxygen required by the organic substances in water to oxidize them by a strong chemical oxidant. It is used to measure the oxygen required for the oxidation and oxidizable inorganic matter, corrected for the influence of chlorides in the sample. COD indicate the amount of oxygen required to oxidize the carbonaceous matter. The organic matter includes both biodegradable as well as non biodegradable substances.

The COD method is used as a supplement to BOD. The dichromate reflux method for COD test is selected to measure the pollution strength and wastes etc. The advantage of this test is the short time. COD is always greater than BOD and the difference gives a routine estimate of the non biodegradable part. The lower the ratio of BOD/COD, the higher is the fraction of slowly biodegradable compounds.

The principle involved in the determination of COD is that when the waste water sample is refluxed with a known excess of potassium dichromate in H_2SO_4 solution in presence of $AgSO_4$ (as catalyst) and $HgSO_4$ (to eliminate interference due to chloride), the organic matter of the sample is oxidized to water, CO_2 and ammonia. The excess dichromate remaining unreacted in the solution is titrated with a standard solution of ferrous ammonium sulphate.

In the dichromate reflux method, 50 ml of the sample was taken and the COD was determined by refluxing the samples with 25 ml of 0.125 N potassium dichromate in a strongly acidic medium in the presence of a catalyst $AgSO_4$ (5 ml) and $HgSO_4$. 30 ml of H_2SO_4 is added and is refluxed for two hours. The excess of potassium dichromate remaining after reaction is titrated against a standard 0.1 N ferrous ammonium sulphate using ferroin as an indicator. The end point is indicated by a sharp colour change from blue-green to reddish brown.

The same procedure was conducted for blank using 50 ml distilled water in place of sample.

3.2.9 Total Hardness

The hardness of water is not a pollution parameter, but indicates water quality, mainly in terms of Ca^{2+} and Mg^{2+} ions, expressed as Calcium carbonate[39]. Hardness in water is caused by dissolved calcium and, to a lesser extent, magnesium. Hardness is a property of water which prevents lather formation with soap and increases the boiling point of water.

There are two types of hardness: temporary hardness and permanent hardness. Temporary hardness is caused by bicarbonates and carbonates of calcium and magnesium which can be removed simply by boiling the water on the other hand, the presence of sulphates and chlorides of calcium and magnesium in water causes permanent hardness.

Water about 150 mg/L of total hardness cause no harmful effects upon the health of the consumers. The use of hard waters however is limited because of excessive soap consumption in home and laundries [37]. Depending on pH and alkalinity, hardness above about 200 mg/L can result in scale deposition, particularly on heating. Soft waters with a hardness of less than about 100 mg/L have a low buffering capacity and may be more corrosive to water pipes. Public acceptability of the degree of hardness may vary considerably from one community to another, depending on local conditions, and the taste of water with hardness in excess of 500 mg/L is tolerated by consumers in some instances [35].

Total hardness is determined by EDTA titration method using Eriochrome black-T as indicator. The principle involved in this titration is that, the Calcium and magnesium form a complex of wine red colour with Eriochrome black-T at pH 10.0±0.1. EDTA has got a strong affinity towards Ca^{2+} and Mg^{2+} and, therefore, by addition of EDTA, the former complex is broken down and a new complex of blue colour is formed.

50 ml of the water sample was taken in a 200 ml conical flask.1ml of buffer solution was added. The solution became wine red after dissolving 100mg of Erichrome black-T indicator. The content was titrated with 0.01M EDTA solution until red colour changed to blue.

3.2.10 Calcium Hardness

Calcium is one of the most abundant elements in natural waters. Calcium is usually one of the most important contributors to hardness. It is an essential element and human body requires approximately 0.7 to 2.0 gm of calcium per day as food element, which cannot be supplied even by hard water. Even though human body requires some amount of calcium per day as food element, excessive amounts can lead to formation of kidney or gall bladder stones. But high calcium content water causes more soap consumption and other cleaning agents for washing, bathing and laundering. Calcium is an important nutrient for plants as well as crops.

Many indicators such as ammonium purpurate, calcon etc. form a complex with only calcium but not with magnesium at pH 12.3 (Mg^{2+} gets precipitated as $Mg(OH)_2$) [39]. As EDTA has a higher affinity towards calcium, the former complex is broken down and a new complex is formed. However, EDTA has a property to combine with both Ca^{2+} and Mg^{2+}, therefore magnesium is largely precipitated as its hydroxide at sufficiently higher pH.

Calcium is determined by EDTA titration method.50ml of the sample was taken in a conical flask. Sufficient amount of NaOH (20%) solution is then added to the sample to bring the pH to about 12. A pink colour develops on addition of 100 mg of murexide indicator. The content is then titrated with 0.01M EDTA solution until the pink colour changes to purple.

3.2.11 Magnesium Hardness

Magnesium is relatively non toxic to man and is an essential element for human being. Magnesium is the fourth most abundant mineral in the body and is essential for good health [40]. It helps and maintains normal muscle and nerve function, keeps hearth rhythm steady, supports a healthy immune system and keeps bones strong. It also helps to regulate blood sugar levels, promotes normal blood pressure and is known to be involved in energy metabolism and protein synthesis [41]. Magnesium occurs in all kind of natural waters with calcium but its concentration remains generally lower than the calcium. Magnesium contributes to hardness. Magnesium in water is undesirable for industrial purpose as it is a major scale forming substance.

Magnesium is an important parameter for assessing the physiochemical characteristic of water. The recommended value of magnesium content in domestic water supply is 30.0 mg/l. The daily magnesium requirement of an average person is 400 mg [42].

The principle involved in the estimation of calcium and magnesium is that, calcium and magnesium forms EDTA complex of wine red colour with Eriochrome Black-T at pH 10.0. The EDTA has stronger affinity for Ca^{2+} and Mg^{2+}, the former complex is broken down and a new complex of blue colour is formed. The value of Mg^{2+} can be obtained by subtracting the value of calcium from the total of Ca^{2+} and Mg^{2+}.

Magnesium is estimated as the difference between total hardness and calcium as calcium carbonate.

fig.4. A Public well in Kohima

fig 5. A River has been reduced to a puddle due to water shortage

fig 6. A muddy pond in Mokokchung district

CHAPTER-4

TRACE ELEMENTS

4.1 Introduction

The term trace metal elements are generally found in little concentration in the natural bio-system [43]. The trace elements are divided according to their importance to the human body into two groups. The trace elements which include the elements silver, aluminum, cadmium, gold, lead and mercury, which have no biological role, are non-essential and potentially toxic to living organisms, especially microorganisms [44]. The second group is called the essential trace elements which embrace calcium, cobalt, chromium, copper, iron, potassium, magnesium, manganese, sodium, nickel and zinc. These elements play an integral role in the life processes of living organisms. They serve as micronutrients and are utilized for redox-processes, to stabilize molecules *via* electrostatic interactions, as components of various enzymes and regulation of osmotic pressure. However, these metals, both essential and non-essential metals at high levels, can destroy cell membranes, modify enzyme specificity, disrupt cellular functions and damage the structure of DNA [45]. The trace heavy metals such as Pb, Cd and Hg present in water above the permissible limit are very serious and dangerous as these heavy metals have a great affinity for sulphur and sulphur bonds in the enzymes of living beings and may cause immobilizing to human being.

In this study the trace elements analyzed include Pb, Cd, As, Ag, Mn, Hg, Zn, Fe, Ni, Ca and Mg. Many of these trace elements are found in polluted water due to the discharge of domestic sewage and industrial effluent directly to the surface and ground water. The presence of trace elements in water may also be because of the biogenic debris which may settle through the water column and deliver some minor elements such as chromium, copper, nickel and zinc.

4.2 Principle involved in the analyses of trace elements in water samples by Atomic Absorption Spectroscopy

The water samples of 1 (one) litre was added with about 5 ml of concentrated hydrochloric acid to acidify the sample upto pH 2.0 so as to minimize adsorption [39, 46] of metals on the container walls. The volume of the sample was concentrated to 50ml by keeping and evaporating the sample over the hot plate at 70^0 C - 80^0 C for 10-12 hours. The sample was allowed to cool and was taken for the analysis of trace elements using Atomic Absorption Spectrometry (Perkin Elmer 3110) .

The principle involved in AAS technique is that the sample is converted into atomic vapour by spraying the sample into a flame (air/acetylene). The flame volatilizes the solvent and ultimately causes dissociation of the minute, solid, solute particles into atoms. These atoms absorb heat energy by promoting electrons to a higher energy level and on relaxing to initial ground states the excess energy is released as characteristic radiation.

$$A + \text{Heat} \longleftrightarrow A^* \underset{\text{Absorption}}{\overset{\text{Emission}}{\longleftrightarrow}} A + h\nu$$

Different elements show different characteristic radiation. Thus it enables us to determine different elements present in the sample quantitatively.

4.3. Trace elements in water

4.3.1 Lead

Lead is a physiologically unessential and potentially harmful metal which contaminates the environment. Lead is a serious cumulative body poison. Lead is classified as being potentially hazardous and toxic to most forms of life [47]. It can accumulate in many biological system units and tends to deposit in the bones. The principal vehicle for the transport of lead from the intestine to the various body tissues is the red blood cell [48] in which lead is bound primarily to hemoglobin. Following its absorption, lead appears both in a soft tissue pool, consisting of the blood, liver, lungs, spleen, kidneys, and bone marrow, which is rapidly turned over, and in a more slowly turn over skeletal pool. The half-life of lead in blood and soft tissues is about 36–40 days for adults [49] so that blood lead concentrations reflect only the intake of the previous 3–5 weeks.

The significant toxic effect associated with lead on the nervous system, kidney, liver etc have been recognized for a long time. It replaces calcium in bones and poisons the nerves and hence affects the brain. Besides, it produces slight alteration in the mental direction, dullness and weak memory. Moreover, it contradicts fertility besides having effects which distort embryos in rodents [50, 51] in animals including man, gastro-intestinal absorption of lead ranges between 5-15 percent of the total amount ingested. However children have been shown to absorb lead 4-5 times much more [52, 53] than the adults, about 40 percent of it. More than 90 percent of the lead absorbed goes to blood, where it can be detected in red blood cell associated with its membrane and hemoglobin. Later it is distributed to liver, kidney and bones including teeth.

Lead does not occur practically in any natural water. It is present in water to some extent as a result of its dissolution from natural sources but lead enters into water bodies primarily from industrial effluent, mine and smelter discharges or from dissolution of old leads and household plumbing systems in which the pipes, solder, fittings, or service

connections to homes usually contains lead. PVC pipes also contain lead compounds that can readily be leached out resulting in high lead concentrations in drinking-water. The amount of lead dissolved from the plumbing system depends on several factors, including the presence of chloride and dissolved oxygen, pH, temperature, water softness, and standing time of the water, soft, acidic water being the most plumbosolvent [54, 55]. The level of lead in drinking-water may be reduced by corrosion-control measures such as the addition of lime and the adjustment of the pH in the distribution system from <7 to 8–9 [56, 57].Natural waters generally contain lead up to 200ppb.The WHO standard for lead in drinking water is 0.01 mg/L [35].

In this study, the presence of lead in water sample was determined by taking 10ml of the pre-concentrated sample using Atomic Absorption Spectrophotometer at 217 nm analytical wavelengths and 1.2 nm slit width

4.3.2 Cadmium

Cadmium is a non essential element for living organism [58]. Cadmium occurs in nature in association with zinc minerals. It is highly toxic and is responsible for many cases of poisoning through food. Cadmium has the capability to inhibit the ion exchange altering the permeability characteristics of the cell membrane. Moreover it replaces zinc in specific enzymes leading to the disability of the function of these enzymes as well as affecting of metabolism of glycogen, cholesterol and protein in the tissues of liver, kidney and the muscles of rats. It accumulates mainly in the kidney and the liver, where high concentration gives rise to chronic kidney dysfunction. However it is not certain whether they are human carcinogens, but cadmium replaces calcium in bones making them non rigid [59].Cadmium is considered as a significant environmental pollutant with profound toxic effects on aquatic animals. It causes coagulation of the external mucous layer in fishes leading to deficiency in the oxygen level in the tissues as well as changing the salt equilibrium and the incretion of the produced waste materials [45, 60]. Small quantities of Cadmium cause adverse changes in the arteries of human kidney[39].It is also

widely accepted that no level of lead or cadmium in blood should be considered safe for children and hence every efforts should be made to ensure that their environment remains free from any such toxic metals [61].

Cadmium metal is used in the steel industry and in plastics. Cadmium compounds are widely used in batteries. Cadmium enters water through industrial discharges, mining and metallurgical operations, electroplating industry, plastics, nickel cadmium batteries, paints, and combustion of fossil fuels. Cadmium can be used in pigments to impart bright colours to toys in order to attract children [61]. Cadmium contamination of water may also come from the use of metallic and plastic pipes. There is a progressive accumulation of cadmium in soft tissues of the body, particularly in kidney and liver [45]. Due to its potential for gradual accumulation much concern has been expressed about the regularly growing levels of cadmium in cereals, vegetables and other materials. The metal can exert a number of detrimental effects on health. The maximum permissible limit for cadmium in drinking water is 0.003 mg/L [35].

The presence of Cadmium in water sample was determined by taking 10 ml of the pre concentrated sample using Atomic Absorption Spectrophotometer at 229 nm analytical wavelengths.

4.3.3 Arsenic

The occurrence of arsenic in natural waters is rare. Arsenic is introduced into water through dissolution of rocks, minerals and ores, from industrial effluents, including mining wastes, and via atmospheric deposition[35], industrial discharges or the application of insecticides and pesticides. Arsenic exists mostly in oxidation states of +5 and +3. It is widely distributed throughout the Earth's crust, most often as arsenic sulfide or as metal arsenates and arsenide. In water, it is most likely to be present as arsenate, with an oxidation state of +5, if the water is oxygenated. However, under reducing conditions (<200 mv), it is more likely to be present as arsenite with an oxidation state of +3 [35].

Arsenic in drinking water is highly undesirable because of its high toxicity. It is a cumulative poison and possesses carcinogenic properties. Symptoms of arsenicosis are primarily manifested in the forms of different types of skin diseases like skin lesions, hyperkeratosis, melanosis etc. General adverse health effects that are associated with human exposure to arsenicals include cardiovascular diseases, developmental abnormalities, neurological and neurobehavioral disorders, diabetes, hearing loss, fibrosis of the liver and lung, hematological disorders, black foot disease and cancers [62].

Acute arsenic poisoning arises from ingestion of as little as 100 mg Arsenic. The WHO guideline for drinking water has prescribed a maximum permissible limit of 0.01 mg/l for arsenic [35].

Analyses of arsenic in the water samples was done after the arsenic was pre-reduced from As^{+5} to As^{+3} prior to determination to prevent any interferences. The pre-reduction was performed with KI solution (KI+Ascorbic acid) in semi-concentrated (5mol/L) HCl solution and the time for reduction was 30 minutes [24]. 10ml of pre-reduced water sample were analyzed using Atomic Absorption Spectrophotometer at 193.7 nm analytical wavelengths and 0.7 nm slith width.

4.3.4 Silver

Silver is a non-essential trace element which has no biological role to the human body [45].Silver occurs naturally mainly in the form of its very insoluble and immobile oxides, sulfides and some salts. A sign of excess of silver in human body is argyria, a condition in which skin and hair are heavily discoloured by silver in the tissues [35].

Silver at low concentration is not a toxic metal; however at higher concentration it becomes potentially toxic to living organism, especially microorganisms. The concentration of silver in the range 0.4 to 1ppb is reported to cause pathologic changes in the kidneys, liver and spleen of rats [39]. In drinking water the WHO permissible level of Silver is 0.05 mg/L.

Silver in water sample was determined by taking 10 ml of the pre concentrated sample using Atomic Absorption Spectrophotometer at 328 nm analytical wavelengths.

4.3.5 Iron

Iron usually exists in natural water both in Fe^{2+} and Fe^{3+} forms. It may occur in dissolved state as well as in the colloidal state that may be peptized by organic matter, in inorganic or organic complexes or in relatively coarse suspended particles. Surface waters contain less than 1 ppm of iron [39]. However ground water and acid surface drainage contain much higher levels of iron. Iron is essential in the activation of the function of the living organisms. Iron has a special importance in the life of human beings as well as living organisms in the botanical and zoological kingdoms, where it functions as a respiratory pigment in addition to its engagement in the structure of the catalyze enzyme [45, 63]. However, water containing more than 2 ppm iron causes staining of clothes, porcelain and gives a bitter astringent taste [39]. The permissible limit for filterable iron in drinking water is 0.3mg/L [35].

The presence of iron in drinking water creates problems when it is present in large amounts in water. It imparts colour and also develops turbidity when exposed to air due to its conversion into ferric states. The water becomes unacceptable for drinking purposes from an aesthetic point of view. Further it interferes with laundering operation, imparts objectionable stains, difficulties in the distribution system and imparts typical taste even at low concentration [64].

Iron presence in water sample was determined by taking 10ml of the pre-concentrated sample using Atomic Absorption Spectrophotometer at 248 nm analytical wavelengths and 0.2 nm slit width.

4.3.6 Copper

Copper is one of the essential elements for human being. The daily requirement of Copper for humans is about 2.0 mg [39].Copper has a special importance as a respiratory pigment, which transfers electrons within the cytochrome system [65].Copper is essential as a constituent of some metaloenzymes and is required in hemoglobin synthesis and in the catalysis of metabolic oxidation [42, 66]. Copper salts are used in water supply system for controlling the biological growths, in reservoirs and distribution pipes and for catalyzing

the oxidation of manganese [39]. It is mainly through food and water that humans take up copper. Soluble copper concentration in drinking water ranges between 1.5 to 2.4 mg/L in urban areas while in rural areas it is usually well below 1 mg/L. In plants low levels of copper are essential for normal activity of a number of enzymes and for chlorophyll synthesis. However, at a slightly higher concentration copper is the most toxic element after mercury. Inhibition of growth occurs at concentration less than 0.1 ppm in majority of plant species. Copper is found in surface water, groundwater, seawater and drinking-water, but it is primarily present in complexes or as particulate matter [67]. In an unpolluted zone of the river Periyar in India, copper concentrations ranged from 0.0008 to 0.010 mg/litre [68]. Copper concentrations in drinking-water vary widely as a result of variations in water characteristics, such as pH, hardness and copper availability in the distribution system with the primary source most often being the corrosion of interior copper plumbing [69]. The corrosion of copper containing alloys in pipe fitting may introduce measurable amount of copper into the water in localized pipe system [39]. Copper contamination of the environment is largely due to its release by industrial units producing non-ferrous metal, fertilizers, disposal of solid waste from mines and from fly ash produced by combustion of coal and organic matter.

The presence of Copper in water sample was determined by taking 10 ml of the pre concentrated sample using Atomic Absorption Spectrophotometer at 324.8 nm analytical wavelength 1.2 nm slit width.

4.3.7 Zinc

Zinc is an essential and beneficial trace element for both plants and animals. Zinc is essential as a constituent of many enzymes involved in several physiological functions, such as protein synthesis and energy metabolism [42, 70]. It is an essential element in the conservation of the structure and functions of the cell membrane [71]. It plays an important

role in the growth of plants and animals, where it is considered to be one of the important components for about 300 enzymes in plants as well as a number of enzymes in the humans such as RNA and DNA polymerase, alkaline phophatase and carbonic anhydrase [72]. However, despite the fact that zinc has low toxic effect to humans, prolonged consumption of large amounts may give rise to some health complications like dizziness, fatigue and neutropenia. In addition, some reports demonstrated that zinc could be toxic to some aquatic organisms like fish [45, 73].

The concentration of zinc above 5 mg/L causes bitter taste and opalescence in alkaline waters. In recent years, excessive use of zinc has been made in many industrial processes, which include welding and smelting or fabrication of molten metals. These leads to the increase in the concentration of zinc in water as this are not biodegradable and are directly enter into water body through various man made activities. High concentration (above 5 mg/L) of zinc in domestic water is undesirable from aesthetic consideration.

Zinc in water sample was determined by taking 10 ml of the pre concentrated sample using Atomic Absorption Spectrophotometer at 218 nm analytical wavelength 0.8 nm slit width.

4.3.8. Nickel

Nickel is an essential trace element for human being. Nickel takes part in the ordinary metabolism in micro-organisms that fix the nitrogen by affecting the hydrogenise enzyme [71]. A number of studies have pointed out that nickel has a nutrient importance, where it engaged in the composition of the nucleic acids, DNA and RNA. Nickel is needed in small amounts by human body to produce red blood cells; however, in excessive amounts, it can become mildly toxic. Short-term overexposure to nickel is not known to cause any health problems, but long-term exposure can cause decreased body weight, heart and liver damage, and skin irritation. Nickel related health effects

such as cardiovascular and renal effects in animals have been reported [74]. Nickel toxic effects upon humans are related to dermal, lung and nasal sinus cancers [37]. Nickel behaves similarly with copper and may be precipitated either as the oxide or as the metallic nickel in water [75].

The discharge of metal plating wastes, increased use of stainless steel and other nickel containing alloys into water courses contribute nickel in water. In drinking water the WHO permissible level of nickel is 0.02 mg/L.

Nickel in water sample was determined by taking 10 ml of the pre concentrated sample using Atomic Absorption Spectrophotometer at 232 nm analytical wavelengths.

4.3.9 Manganese

Manganese is an essential element for activation of the functions of living organisms. It is engaged in building the connective tissues and bony tissues [65] in the living organisms. Although manganese is not a toxic element, presence of manganese imparts objectionable and tenacious stains to laundry plumbing fixtures. It occurs in solids and rocks as manganese dioxide and can be dissolved in natural waters by the action of anaerobic bacteria[39]. Under reducing conditions, manganese can be leached from the soil and occur in considerable concentrations in ground water. It also occurs in domestic waste water, industrial effluents and receiving strums and thereby enters water bodies.

The WHO permissible level of Manganese in drinking water is 0.1 mg/L [35]. The presence of Manganese in surface and ground water was determined using Atomic Absorption Spectrophotometer at 279.5 nm analytical wavelengths 0.5 nm slit width by taking 10 ml of the pre concentrated sample.

fig 7. A public well at upper Chandmari, Kohima

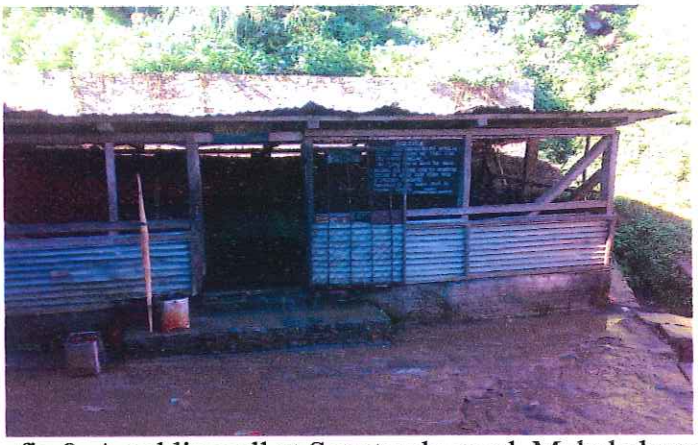


fig 8. A public well at Sangtamla ward, Mokokchung

fig 9. A public well at Penli ward, Mokokchung

CHAPTER- 5

EXPERIMENTAL OBSERVATIONS

5.1. Physiochemical observations

A large number of spring and well water sources from different districts of Nagaland were identified and samples was collected during winter (January-March) and summer (June-August) starting from January 2005 to July 2008 for four continuous years. The samples was collected from 20-30 sources each from seven districts (Kohima, Dimapur, Mokokchung, Tuensang, Wokha, Lumami under Zunheboto, Tseminyu and Ungma) for every season covering mainly the urban area of Nagaland.

The analysis of physiochemical properties such as pH, conductivity, temperature, total dissolved substances and dissolved gases of water samples was collected in a clean plastic container of 1L capacity. The entire container was tightly capped and the stopper, whenever necessary was replaced in such a manner so as to entrap as little air as possible.

It was ensured that, the samples for analysis of physiochemical characteristics was determined as quickly as possible on the spot ,using water quality testing kits (eutech cyperscan, Singapore) in order to get an accurate result. In some unavoidable cases, the samples were carefully brought to the laboratory for analysis using pH meter and conductometer.

The result of the experimental observations of physiochemical characteristics of representative samples are given in the following tables (Table no. 5.1.1.1 to 5.1.8.2)

5.1: Result of Physiochemical characteristic of spring and well water of some selected districts in Nagaland

Table: 5.1.1.1.Kohima

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Science College road(forest dept water sources)	k-1	P^H	7.67	7.78	7.45	7.65	7.09	7.10	6.49	6.86
		Conductivity μscm^{-1}	91	102	167	121	121	97	81	60
		TDS ppm	46	52	84	63	61	49	42	30
		Tempt. ^0c	14.2	18	14.2	19	15	18	15.2	19.2
Science College road (near CNBC office	k-2	P^H	7.05	7.09	6.82	6.81	6.51	6.65	6.51	6.75
		Conductivity μscm^{-1}	89	98	78	77	61	56	61	69
		TDS ppm	47	49	39	38	31	28	31	36
		Tempt. ^0c	15	18.6	14.7	18	16	18	14.6	20
Lower Chandmari -Ag road public well near bridge	k-3	P^H	6.68	6.69	6.26	6.45	6.48	6.67	6.73	6.64
		Conductivity μscm^{-1}	729	821	1362	1262	1410	1210	935	870
		TDS ppm	365	410	676	631	705	605	468	437
		Tempt. ^0c	13.9	19	16	19	17	20	14.8	21
Upper Chandmari public well (near Home guard office	k-4	P^H	6.53	6.59	6.40	6.46	6.57	6.87	6.51	6.85
		Conductivity μscm^{-1}	899	993	1033	1023	1098	998	1041	989
		TDS ppm	450	486	516	511	549	499	521	495
		Tempt. ^0c	142	18.7	16.4	19	15.3	20	15	18
Midland colony public well	k-5	P^H	6.65	6.67	6.54	6.61	6.62	6.61	6.45	6.52
		Conductivity μscm^{-1}	935	930	1186	1380	1297	1291	1394	1294
		TDS ppm	472	470	593	690	649	646	697	647
		Tempt. ^0c	14.6	19	16.3	19.3	14.6	19	16.8	19.3

Table:5.1.1.2.Kohima

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
NH-39 water fetch by kohima town dwellers	k-6	P^H	7.11	7.16	7.11	7.24	7.33	7.53	7.41	7.34
		Conductivity μscm^{-1}	465	378	473	404	341	322	412	398
		TDS ppm	233	189	236	202	172	161	206	199
		Tempt. ^0c	15	21	16	20	16.7	18	14.3	21
Kohima town garbage dumping area NH-39	k-7	P^H	7.03	7.13	7.03	7.03	7.25	7.27	7.12	7.32
		Conductivity μscm^{-1}	989	698	789	707	762	699	812	756
		TDS ppm	495	439	395	354	381	350	406	378
		Tempt. ^0c	15.2	22	15.8	22	15.2	20	14.5	21
Ground water dte of printing & stationary	k-8	P^H	6.81	6.83	6.75	6.77	6.78	6.88	6.61	6.75
		Conductivity μscm^{-1}	1123	1101	1125	1221	1255	1198	1301	1200
		TDS ppm	567	551	560	611	628	599	631	600
		Tempt. ^0c	14.9	19	16	20	16	18.3	14.2	21
Chandmari-Ag road near transfoemer (tube well)	k-9	P^H	5.78	5.79	5.67	5.71	5.61	5.66	5.56	5.76
		Conductivity μscm^{-1}	724	704	745	734	767	726	798	797
		TDS ppm	362	352	373	367	384	363	398	397
		Tempt. ^0c	14.9	18.9	16	18.6	15	21	15	20
PWD public well (Tube well)	k-10	P^H	6.78	6.98	6.64	6.87	6.88	6.87	6.61	6.67
		Conductivity μscm^{-1}	1238	1302	1438	1400	1025	989	1528	1535
		TDS ppm	619	652	719	700	513	495	764	768
		Tempt. ^0c	14.7	21	16.5	20	16.3	19	14.5	20.5

Table:5.1.1.3.Kohima

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Chandmari-midland boundhary (behind bridge)	k-11	P^H	6.67	6.71	6.67	6.64	6.57	6.75	6.61	6.76
		Conductivity μscm^{-1}	889	845	979	990	1310	1210	1228	1098
		TDS ppm	423	445	489	490	758	605	684	549
		Tempt. ^0c	15	19	15	17.1	15.8	19.4	16	21
AG colony(facing lower chandmari	k-12	P^H	6.54	6.71	6.50	6.76	6.61	6.69	6.32	6.53
		Conductivity μscm^{-1}	276	313	883	799	851	901	832	809
		TDS ppm	137	157	442	400	425	450	418	404
		Tempt. ^0c	16	19	16	19	15	19	17	21
NH-39(near mezoma village)	k-13	P^H	7.09	7.11	7.44	7.83	7.57	7.67	7.26	7.67
		Conductivity μscm^{-1}	214	189	102	122	105	115	212	145
		TDS ppm	107	95	51	61	53	57	106	72
		Tempt. ^0c	14.5	19	16.4	21	17	22	16	19
Lerie colony Site-I	k-14	P^H	5.65	5.67	5.69	5.74	5.59	5.60	5.63	5.63
		Conductivity μscm^{-1}	201	223	469	501	453	521	439	432
		TDS ppm	100	112	235	250	227	261	219	216
		Tempt. ^0c	15	18	14.9	19	16	20	16	19
Lerie colony Site-II	k-15	P^H	6.54	6.76	6.69	6.89	6.91	6.91	6.68	6.88
		Conductivity μscm^{-1}	548	508	678	657	712	712	704	669
		TDS ppm	274	254	357	329	356	356	352	334
		Tempt. ^0c	16	18.2	16.2	18	17.3	17.3	17	19.8

Table: 5.1.1.4. Kohima

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Lerie colony Site-III	k-16	P^H	6.81	6.97	6.91	6.99	6.91	6.93	6.89	6.90
		Conductivity μscm^{-1}	391	399	424	364	434	400	441	399
		TDS ppm	196	200	212	182	217	200	221	199
		Tempt. ^0c	14.6	19	16.7	18.1	16.5	19.5	16	18
Forest colony Site-I (N/w)	k-17	P^H	7.02	7.12	7.01	7.10	6.78	7.07	6.97	6.99
		Conductivity μscm^{-1}	94	93	132	113	134	107	147	102
		TDS ppm	46	45	66	57	67	54	74	51
		Tempt. ^0c	15	18	16.4	19.4	16	20	16	20
Forest colony Site-II (s/w)	k-18	P^H	6.98	7.05	6.82	6.80	6.81	6.88	6.91	6.90
		Conductivity μscm^{-1}	98	112	87	84	86	79	92	89
		TDS ppm	49	56	44	42	43	40	46	45
		Tempt. ^0c	14	20	16	20	15.4	18	17	19
Agri colony-I	k-19	P^H	6.68	6.69	6.66	6.86	6.72	6.78	6.67	6.73
		Conductivity μscm^{-1}	262	212	262	172	241	187	317	270
		TDS ppm	131	106	131	91	121	94	159	135
		Tempt. ^0c	14.7	20	17	21	15	21	17	20
Upper chandmari public well-II	k-20	P^H	6.87	6.85	6.61	6.96	6.87	6.88	6.86	6.87
		Conductivity μscm^{-1}	321	278	387	343	368	298	341	301
		TDS ppm	169	139	194	172	184	149	171	151
		Tempt. ^0c	146	20	16.5	20	15	21	16	19

Table: 5.1.1.5.Kohima

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Midland site-II	k-21	P^H	6.98	6.98	6.74	6.81	6.77	6.81	6.66	6.87
		Conductivity μscm^{-1}	234	231	385	318	397	297	392	362
		TDS ppm	117	116	193	160	199	149	196	181
		Tempt. ^0c	13.8	19	15.7	18.6	16	18	16	19
Agri colony upper-II	k-22	P^H	7.22	7.23	7.14	7.35	7.13	7.41	7.03	7.01
		Conductivity μscm^{-1}	276	289	373	173	354	241	356	313
		TDS ppm	137	145	187	87	177	121	178	157
		Tempt. ^0c	14	18	16	18.3	15.9	18.9	15.6	19.3
Bayavu site-I	k-23	P^H	7.12	7.10	7.03	7.21	7.16	7.27	7.12	7.19
		Conductivity μscm^{-1}	244	198	321	289	262	266	312	212
		TDS ppm	125	99	162	145	131	133	156	106
		Tempt. ^0c	13.8	19	16.5	20	16.6	20.3	15.8	20.6
Bayavu site-II	k-24	P^H	6.98	7.04	6.88	6.87	6.93	6.93	7.09	7.08
		Conductivity μscm^{-1}	89	130	215	198	255	155	301	187
		TDS ppm	46	69	108	99	129	78	151	94
		Tempt. ^0c	15	18	16.4	19.5	16	19	15.6	19
High School site-I	k-25	P^H	7.18	7.31	7.15	7.21	7.09	7.11	6.99	7.08
		Conductivity μscm^{-1}	191	231	221	121	271	183	161	132
		TDS ppm	96	116	111	61	136	92	81	66
		Tempt. ^0c	137	19	15	19	15	19.7	15	18
High school site-II upper road	k-26	P^H	6.98	7.05	7.03	7.18	6.95	6.98	6.98	7.08
		Conductivity μscm^{-1}	189	98	178	231	197	161	201	199
		TDS ppm	95	49	89	116	98	81	101	100
		Tempt. ^0c	136	18	16	18	15.3	19	16	18.9

Table: 5.1.1.6. Kohima

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
AG colony site-I (N/w)	k-27	P^H	6.61	6.68	6.67	6.76	6.58	6.86	6.79	6.97
		Conductivity μscm^{-1}	221	199	362	236	278	265	270	210
		TDS ppm	111	100	181	118	139	133	135	105
		Tempt. ^0c	15	18.6	16	19	15.8	19	15.6	21
AG colony Site-II(s/w)	k-28	P^H	6.89	6.98	6.47	6.74	6.78	6.87	6.95	6.93
		Conductivity μscm^{-1}	418	389	323	233	298	289	241	253
		TDS ppm	209	125	162	117	117	144	121	126
		Tempt. ^0c	14.6	18	16	18.7	16	19.5	16	20
Midland upper site-II	k-29	P^H	6.74	6.87	6.65	6.74	6.69	6.86	6.75	6.77
		Conductivity μscm^{-1}	481	280	480	278	597	397	523	494
		TDS ppm	240	140	240	139	299	199	262	247
		Tempt. ^0c	15.5	18.9	16.5	19.5	15.6	18.3	15.2	18.9
Paramedical colony site-I	k-30	P^H	7. 01	7. 21	7.29	7.24	7. 13	7. 33	7.21	7.14
		Conductivity μscm^{-1}	572	372	473	373	314	431	431	403
		TDS ppm	287	187	236	187	157	216	216	201
		Tempt. ^0c	16.7	18.7	15.9	19	16.2	19.3	16	19.2
Kohima town garbage dumping area site-II	k-31	P^H	7. 03	7.67	7. 13	7. 30	7.21	7.17	7.23	7.21
		Conductivity μscm^{-1}	889	876	889	789	962	862	932	914
		TDS ppm	445	438	445	395	481	343	466	457
		Tempt. ^0c	148	20	16.3	20.2	16.9	20.2	16	21
Poterlane	k-32	P^H	6.68	6.86	6.77	6.87	6. 78	6. 81	6.69	6.96
		Conductivity μscm^{-1}	512	426	452	421	655	455	666	630
		TDS ppm	256	216	226	211	328	228	333	351
		Tempt. ^0c	14.	19.4	15.7	19.6	15.1	19	16.3	21

Table:5.1.2.1 Dimapur

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
6th mile Dimapur(near petrol pump)	D-1	P^H	6.23	6.27	5.74	6.12	6.68	6.58	6.52	6.65
		Conductivity μscm^{-1}	453	465	433	435	327	322	427	398
		TDS ppm	227	233	202	204	163	160	213	199
		Tempt. ^0c	17	20.7	16.6	21	17	23.1	23	23
Half nagarjan (near govt.hss)	D-2	P^H	6.81	6.78	6.89	6.91	6.88	6.93	6.88	6.97
		Conductivity μscm^{-1}	2333	2023	2180	1820	1896	1968	1937	1861
		TDS ppm	1166	1011	1092	912	948	987	981	931
		Tempt. ^0c	16	21	16.2	19.6	17	23.2	17.8	22.8
Naga cemetry colony	D-3	P^H	6.67	6.89	6.90	6.97	6.73	6.79	6.87	6.88
		Conductivity μscm^{-1}	412	423	555	355	604	561	714	681
		TDS ppm	206	216	277	178	302	281	368	340
		Tempt. ^0c	166	23	16.9	23	16.8	22.2	16.5	22.5
Signal colony Site-I	D-4	P^H	6.78	6.91	6.80	6.78	6.67	6.76	6.67	6.76
		Conductivity μscm^{-1}	688	743	674	698	734	698	734	534
		TDS ppm	344	372	335	349	366	349	366	267
		Tempt. ^0c	18	23	17	22.2	17	23.3	17.3	23
Dubagaon bricks factory	D-5	P^H	6.78	6.87	6.83	6.85	6.87	6.85	6.91	6.96
		Conductivity μscm^{-1}	889	789	780	809	1213	1073	1098	998
		TDS ppm	445	491	390	404	537	607	543	499
		Tempt. ^0c	167	22.7	16.9	23	17	23	16.7	23.1

Table: 5.1.2.2.Dimapur

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Dubagaon factory(adjoining to d-5)	D-6	P^H	6.85	6.93	6.75	6.87	6.68	6.86	6.89	6.88
		Conductivity μscm^{-1}	743	634	785	585	812	689	810	768
		TDS ppm	378	317	369	295	406	345	405	384
		Tempt. ^0c	17	23.2	17	23	17	23.5	17	23.4
7th mile lpg refilling	D-7	P^H	6.98	7.10	7.10	7.21	7.09	7.08	7.02	6.99
		Conductivity μscm^{-1}	114	241	214	204	241	214	310	289
		TDS ppm	57	121	108	102	120	107	155	145
		Tempt. ^0c	17	23	16.8	24	16.9	22.5	17.8	23.8
Signal site-II	D-8	P^H	7.34	7.43	7.11	7.12	7.09	7.12	7.23	7.20
		Conductivity μscm^{-1}	523	323	499	249	640	440	543	447
		TDS ppm	276	162	250	125	321	220	272	224
		Tempt. ^0c	17.7	23.1	16.8	23.1	17	22.9	17	24
Padumpukri (near panchayat hall)	D-9	P^H	7.31	7.47	7.63	7.56	7.34	7.43	7.59	7.45
		Conductivity μscm^{-1}	578	278	509	398	686	512	605	622
		TDS ppm	286	139	256	199	344	256	352	311
		Tempt. ^0c	16.6	22.5	17	24	16.8	23.9	17.2	23.2
Padumpukri site-II	D-10	P^H	7.23	7.53	7.53	7.55	7.45	7.64	7.61	7.63
		Conductivity μscm^{-1}	686	486	686	487	891	798	698	704
		TDS ppm	343	243	343	244	448	399	349	352
		Tempt. ^0c	17	23.8	16.9	23.4	17	24	17.2	23.4

Table: 5.1.2.3. Dimapur

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
3th mile Dimapur site-I	D-11	P^H	6.67	6.83	6.74	6.84	6.87	6.78	6.71	6.76
		Conductivity μscm^{-1}	387	452	437	413	427	325	397	379
		TDS ppm	194	229	219	207	214	163	199	189
		Tempt. ^0c	17.2	23	17	23.2	17	24	17.1	23
3th mile Dimapur site-II	D-12	P^H	6.81	6.98	6.67	6.91	6.79	6.94	6.87	6.83
		Conductivity μscm^{-1}	469	589	620	478	668	568	637	587
		TDS ppm	235	295	310	239	384	284	319	294
		Tempt. ^0c	17.5	23.2	16.7	22.6	17	23.8	16.8	22
Kushibill Site-I	D-13	P^H	6.89	6.97	6.79	6.90	6.73	6.79	6.77	6.87
		Conductivity μscm^{-1}	654	456	515	513	540	504	621	614
		TDS ppm	327	228	258	257	270	252	311	307
		Tempt. ^0c	16.8	23.8	17	23.7	16.7	22.4	16.9	23
Kushibill Site-II	D-14	P^H	6.89	6.75	6.86	6.91	6.81	6.89	6.77	6.87
		Conductivity μscm^{-1}	665	545	456	433	621	482	634	533
		TDS ppm	336	273	228	217	311	241	317	267
		Tempt. ^0c	16.5	22.5	16.4	22.4	16.6	22.7	16.7	22.4
Site-III Kushibill	D-15	P^H	6.97	6.93	6.78	6.97	6.87	6.98	6.89	6.98
		Conductivity μscm^{-1}	656	673	637	599	613	571	474	467
		TDS ppm	328	337	337	300	306	286	237	234
		Tempt. ^0c	16.6	22.6	17	22.3	16.9	22.3	17	22.5

Table: 5.1.2.4. Dimapur

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
4th mile site-I	D-16	P^H	6.89	7.04	6.73	6.95	6.89	6.96	6.91	6.99
		Conductivity μscm^{-1}	599	409	585	468	512	499	510	498
		TDS ppm	300	204	293	234	256	250	255	249
		Tempt. ^0c	17	23	16.5	21.7	17.2	22.8	17.2	24
4th mile site-II	D-17	P^H	7. 07	6.99	7. 01	6.89	7.08	7.05	7.03	6.99
		Conductivity μscm^{-1}	236	241	233	254	245	237	302	311
		TDS ppm	118	121	117	127	123	119	151	156
		Tempt. ^0c	16.8	22.3	17	22.2	16.8	22.4	17	23
Purana bazar site-I	D-18	P^H	7.09	7.20	7.12	7.21	7.09	7.29	7.23	7.32
		Conductivity μscm^{-1}	482	428	499	389	640	514	543	514
		TDS ppm	247	214	250	195	321	257	272	257
		Tempt. ^0c	17.1	23.5	16.9	23	17	23.1	16.7	23.5
Purana bazaar Site-II	D-19	P^H	7.31	7.13	7.13	7.21	7.17	7.11	7.29	7.22
		Conductivity μscm^{-1}	495	501	509	567	686	699	643	589
		TDS ppm	248	251	256	284	344	349	321	295
		Tempt. ^0c	16.8	22.3	17	22.3	17	23.2	17.2	23.3
Purana bazaar Site-III	D-20	P^H	7.28	7.31	7.12	7.21	7.13	7.28	7.03	7.12
		Conductivity μscm^{-1}	612	562	586	543	603	600	624	567
		TDS ppm	307	281	293	272	301	300	312	284
		Tempt. ^0c	17	23	16.8	22.6	17	22.9	16	22.3

Table: 5.1.2.5.Dimapur

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
PWD site-I	D-21	P^H	6.86	6.89	6.76	6.67	6.88	6.88	6.79	6.79
		Conductivity μscm^{-1}	452	225	437	473	472	427	421	356
		TDS ppm	235	113	219	237	241	214	211	178
		Tempt. ^0c	16.5	20.4	16	19.9	15.8	22	17	23.2
PWD site-II	D-22	P^H	6.75	6.81	6.97	6.95	6.91	6.95	6.87	6.99
		Conductivity μscm^{-1}	280	223	320	312	468	386	337	333
		TDS ppm	171	112	160	166	234	193	169	167
		Tempt. ^0c	16.2	19.3	16.4	19.8	16.3	21.2	16.4	22
Duncan site-I	D-23	P^H	6.67	6.87	6.69	6.99	6.23	6.79	6.88	6.98
		Conductivity μscm^{-1}	456	398	455	387	504	333	614	644
		TDS ppm	229	199	228	194	252	166	307	322
		Tempt. ^0c	16.8	21.8	15.9	21.4	16	23	16.4	21
Duncan Site-II	D-24	P^H	6.88	6.91	6.71	6.88	6.90	6.92	6.87	6.97
		Conductivity μscm^{-1}	743	649	643	534	634	643	513	534
		TDS ppm	372	325	322	267	317	322	257	267
		Tempt. ^0c	16	21.8	16.3	22	15.9	21	16	23
PWD site-III	D-25	P^H	6.77	6.89	6.83	6.88	6.77	6.86	6.78	6.91
		Conductivity μscm^{-1}	383	338	617	567	537	473	745	789
		TDS ppm	179	169	309	284	269	237	373	294
		Tempt. ^0c	16.7	20.9	15.8	21	16.8	23	16.5	23.2

Table: 5.1.2.6. Dimapur

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
5th mile site-I	D-26	P^H	6.89	6.98	6.95	6.94	6.88	6.98	6.79	6.77
		Conductivity μscm^{-1}	685	658	785	758	801	767	789	738
		TDS ppm	353	329	393	379	400	384	395	359
		Tempt. ^0c	16.5	22	16	22	16	24	16.3	23
5th mile site-II	D-27	P^H	7.11	7.03	7.10	7.06	7.18	7.11	6.99	6.91
		Conductivity μscm^{-1}	314	303	334	314	256	235	316	313
		TDS ppm	157	152	167	157	128	118	158	152
		Tempt. ^0c	16.4	23.3	15.8	23.4	16.5	23	17	23.2
Signal site-III	D-28	P^H	7. 12	7. 21	7.21	7.22	7.09	7.22	7.23	7.32
		Conductivity μscm^{-1}	512	489	512	499	540	488	589	478
		TDS ppm	256	245	256	2509	270	244	295	239
		Tempt. ^0c	15.9	21	16.3	21.9	15.8	22	16.7	23
Padumpukri middle site-III	D-29	P^H	7.26	7.22	7.21	7.12	7.23	7.22	7.27	7.32
		Conductivity μscm^{-1}	612	601	610	566	609	611	648	644
		TDS ppm	306	300	305	283	336	306	324	322
		Tempt. ^0c	16.5	23.5	17	23	16.4	22.5	16.8	22
Padumpukri inner site-IV	D-30	P^H	7.22	7.24	7.53	7.33	7.12	7.24	7.31	7.56
		Conductivity μscm^{-1}	668	686	586	568	729	667	717	689
		TDS ppm	334	393	293	284	365	334	359	345
		Tempt. ^0c	15.8	23.3	16.3	23.2	16.8	23	16.7	24

Table: 5.1.3.1. Mokokchung

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Sangtemla ward mandir well site-I	M-1	P^H	6.65	6.56	7.42	7.22	7.31	7.33	7.12	7.21
		Conductivity μscm^{-1}	227	163	487	478	489	468	491	402
		TDS ppm	114	82	243	239	245	234	245	201
		Tempt. ^0c	15.6	19	16	19.6	15.9	18.9	16	19.8
Sangtemla ward site-II	M-2	P^H	6.73	6.89	7.12	7.25	7.23	7.20	7.12	7.22
		Conductivity μscm^{-1}	327	312	412	298	398	389	391	393
		TDS ppm	164	156	206	149	199	195	196	197
		Tempt. ^0c	16	18.3	15.8	19.8	16	19.2	15.8	18.7
Sangtemla ward site-III (n/w)	M-3	P^H	6.83	6.88	6.99	7.03	7.12	7.21	7.09	7.29
		Conductivity μscm^{-1}	412	387	322	232	332	323	376	411
		TDS ppm	206	194	161	116	166	162	188	206
		Tempt. ^0c	15.5	18.8	16.3	20.1	16.2	21	16	21
Aongza ward Site-I	M-4	P^H	6.63	6.71	6.75	6.57	6.78	6.84	6.68	6.82
		Conductivity μscm^{-1}	715	678	673	487	581	518	556	565
		TDS ppm	368	339	340	244	291	259	278	287
		Tempt. ^0c	15.6	19	15.7	19.9	15.8	20.4	15.7	21
Aongza ward site-II (s/w)	M-5	P^H	6.86	6.88	6.78	6.88	6.80	6.88	6.69	6.89
		Conductivity μscm^{-1}	545	445	640	599	611	589	625	643
		TDS ppm	273	223	320	300	306	295	313	321
		Tempt. ^0c	16	19.7	15.8	19.7	16	21	16.1	20

Table: 5.1.3.2.Mokokchung

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Aongza ward site-III (n/w)	M-6	P^H	6.78	6.89	6.69	6.93	6.83	6.91	6.71	6.78
		Conductivity μscm^{-1}	154	189	261	126	249	324	312	288
		TDS ppm	77	96	131	63	125	162	156	144
		Tempt. ^0c	16.2	20.3	15.6	19.3	15.5	19.5	15.8	20
Arkong ward near ongpangkong court site-I	M-7	P^H	6.70	6.77	6.89	7.02	6.70	6.79	6.71	6.91
		Conductivity μscm^{-1}	452	425	438	238	374	347	459	395
		TDS ppm	226	216	219	118	187	174	230	198
		Tempt. ^0c	15.7	21	16.4	21.2	16.3	22.2	15.6	21
Arkong ward near site-II	M-8	P^H	6.89	6.98	6.94	7.01	7.10	7.01	6.93	6.94
		Conductivity μscm^{-1}	525	415	362	326	371	313	402	376
		TDS ppm	263	208	181	163	186	157	201	188
		Tempt. ^0c	16.2	22	16.2	21.6	15.2	22	15.7	20.7
Arkong ward site-III (s/w)	M-9	P^H	6.79	6.96	6.89	6.79	6.77	6.91	6.78	6.88
		Conductivity μscm^{-1}	425	346	462	382	339	393	411	402
		TDS ppm	213	173	231	191	170	197	206	201
		Tempt. ^0c	15.7	20.6	15.7	15.8	15.7	23	15.8	21
Dilong ward below town hall site-I	M-10	P^H	5.70	5.76	5.64	5.63	5.67	5.67	5.66	5.69
		Conductivity μscm^{-1}	412	514	822	798	841	912	927	872
		TDS ppm	206	257	411	399	421	456	464	436
		Tempt. ^0c	16.3	21	16.2	22	16	21.6	15.8	21

Table: 5.1.3.3. Mokokchung

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Dilong ward toward new market site-II	M-11	P^H	6.63	6.76	6.79	6.89	6.81	6.88	6.87	6.88
		Conductivity μscm^{-1}	713	663	617	567	597	489	712	652
		TDS ppm	367	332	309	284	299	245	356	326
		Tempt. ^0c	15.6	22	16.1	21	16	20.9	14.3	22
Dilong ward site-III	M-12	P^H	5.78	5.77	5.67	5.76	5.67	5.63	5.71	5.73
		Conductivity μscm^{-1}	402	323	789	578	898	777	902	888
		TDS ppm	201	161	395	287	449	389	451	444
		Tempt. ^0c	15.7	21	15.9	21.5	14.7	20	15	19.6
Penli ward DC hill upper well (n/w)	M-13	P^H	6.77	6.86	6.81	6.88	6.86	6.80	6.69	6.86
		Conductivity μscm^{-1}	312	231	334	340	299	290	425	542
		TDS ppm	156	116	167	170	150	145	213	271
		Tempt. ^0c	15.8	20.1	15.7	20.9	15.7	21	14.8	20.2
Penli ward DC hill upper well site-I	M-14	P^H	6.83	6.93	6.81	6.89	6.79	6.87	6.71	6.76
		Conductivity μscm^{-1}	332	313	321	309	291	319	325	332
		TDS ppm	166	157	161	155	146	160	163	166
		Tempt. ^0c	15.8	21	16	20.7	15.3	19	14.9	21
Penli ward DC hill lower well Site-II	M-15	P^H	6.59	6.75	6.90	6.95	6.85	6.86	6.61	6.66
		Conductivity μscm^{-1}	120	176	156	260	251	250	301	289
		TDS ppm	60	88	78	131	126	125	151	145
		Tempt. ^0c	15.4	20	15.3	20.5	14.5	19.8	15	20

Table: 5.1.3.4. Mokokchung

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Penli ward lower well khasi lane	M-16	P^H	6.73	6.76	6.78	6.87	6.75	6.85	6.71	6.87
		Conductivity μscm^{-1}	131	89	282	167	262	223	299	319
		TDS ppm	66	45	141	84	131	116	150	160
		Tempt. ^0c	15.6	20.6	15.7	21	15.8	19.8	14.9	19.7
Mokokchung town water supply Tiechepami source.	M-17	P^H	7.28	7.32	7.41	7.44	7.13	7.33	7.10	7.31
		Conductivity μscm^{-1}	125	121	262	226	231	213	202	222
		TDS ppm	63	61	131	113	116	107	101	111
		Tempt. ^0c	16	22	16.2	21	16.4	22	15.6	21
Majakong ward site-I	M-18	P^H	6.82	6.87	6.78	6.98	6.72	6.77	6.87	6.83
		Conductivity μscm^{-1}	212	167	231	213	222	199	212	188
		TDS ppm	106	84	116	107	111	100	106	94
		Tempt. ^0c	15.8	21	15.7	21	15.8	22	14.8	18.9
Majakong ward site-II	M-19	P^H	6.89	6.92	6.93	6.94	6.87	6.98	6.89	6.91
		Conductivity μscm^{-1}	232	223	254	198	231	233	243	234
		TDS ppm	116	112	127	99	116	117	122	117
		Tempt. ^0c	15.6	20	15.7	22	16	21.4	14.9	20.
Sewak upper	M-20	P^H	6.79	6.99	6.97	7.09	7.04	7.11	6.89	7.03
		Conductivity μscm^{-1}	413	431	417	367	379	397	402	420
		TDS ppm	207	216	209	184	190	199	201	210
		Tempt. ^0c	15.7	19.8	16	21	16	22.2	15.6	19.9
Sewak lower	M-21	P^H	6.70	6.67	6.89	6.96	6.89	6.98	6.93	6.97
		Conductivity μscm^{-1}	412	431	422	322	412	233	427	412
		TDS ppm	206	216	211	161	206	117	214	206
		Tempt. ^0c	14.8	18.9	14.3	19.3	14.8	18.9	14.8	19.3

Table: 5.1.3.5.Mokokchung

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Kumlong site-I	M-22	P^H	6.69	6.76	6.78	6.87	6.74	6.84	6.72	6.87
		Conductivity μscm^{-1}	315	302	373	266	481	321	356	287
		TDS ppm	158	151	187	133	241	161	178	144
		Tempt. ^0c	14.8	19	14.8	19.4	15	19.2	14	19.2
Kumlong site-II	M-23	P^H	6.77	6.86	6.88	6.95	6.88	6.87	6.69	6.79
		Conductivity μscm^{-1}	312	198	340	323	399	387	425	432
		TDS ppm	156	99	170	162	200	194	213	216
		Tempt. ^0c	14.7	18.9	15	19.8	15.1	21	14.7	19.8
Kumlong site-III	M-24	P^H	6.79	6.87	6.95	6.96	6.79	6.95	6.80	6.87
		Conductivity μscm^{-1}	220	189	260	136	271	188	301	266
		TDS ppm	110	96	131	68	136	94	151	133
		Tempt. ^0c	15	19	14.7	19.4	14.9	19.2	15	20
Artang ward Site-I	M-25	P^H	6.78	6.87	6.83	6.89	6.76	6.67	6.76	6.77
		Conductivity μscm^{-1}	352	235	338	383	375	357	358	385
		TDS ppm	176	119	169	192	187	179	179	193
		Tempt. ^0c	14.8	18.6	14.8	19.3	14.8	19.5	15	19.8
Artang ward Site-II	M-26	P^H	6.89	6.98	6.87	6. 90	6.81	6.84	6.80	6.85
		Conductivity μscm^{-1}	225	189	362	267	313	300	302	333
		TDS ppm	113	95	181	133	157	150	151	166
		Tempt. ^0c	14.8	19.7	15	21	14.7	22	16	21
Assam rifle area	M-27	P^H	7.10	7.08	7.05	6.98	6.88	6.87	6.78	6.77
		Conductivity μscm^{-1}	325	332	322	288	321	303	292	288
		TDS ppm	163	166	161	144	161	152	146	144
		Tempt. ^0c	14.7	19.6	15	20	14.8	19.7	14.7	20.2

Table.5.1.4.1. Ungma Village under Mokokchung district.

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Sericulture farm,ungma upper	U-1	P^H	7.39	7.43	7.02	7.21	7.12	7.22	7.11	7.21
		Conductivity μscm^{-1}	301	233	121	89	128	123	260	178
		TDS ppm	151	117	61	45	64	63	130	89
		Tempt. ^0c	15	19.9	14.8	18.9	15	21	14.7	19.5
Sericulture farm,ungma lower	U-2	P^H	7.54	7.64	7.23	7.32	7.32	7.22	7.21	7.32
		Conductivity μscm^{-1}	351	315	221	225	228	318	265	256
		TDS ppm	176	158	111	116	114	158	133	128
		Tempt. ^0c	14.6	19.6	14.2	19.8	14.8	21	14.8	20
Tsusenyong tsubo upper	U-3	P^H	7.65	7.56	7.78	7.98	7.81	7.88	7.88	7.87
		Conductivity μscm^{-1}	325	311	380	378	465	406	450	378
		TDS ppm	163	156	190	189	232	203	225	189
		Tempt. ^0c	14.6	18.9	15.3	20.3	15	19.8	14.2	18.9
Tsusenyong tsubo lower	U-4	P^H	7.65	7.76	7.82	7.85	7.83	7.98	7.87	7.78
		Conductivity μscm^{-1}	413	432	389	189	436	336	443	289
		TDS ppm	207	216	195	95	218	169	222	145
		Tempt. ^0c	15.4	18.4	14.5	19.5	14.9	18.9	14	19.5
Arongtsubo upper	U-5	P^H	7.43	7.46	7.10	7.23	7.36	7.43	7.27	7.33
		Conductivity μscm^{-1}	297	291	132	213	371	332	387	365
		TDS ppm	149	141	66	107	185	166	194	183
		Tempt. ^0c	15	19	14.7	19.4	15	19.4	14.3	18.9

Table: 5.1.4.2. Ungma Village under Mokokchung district

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Arongtsubo east	U-6	P^H	7.63	7.45	7.20	7.42	7.33	7.32	7.32	7.33
		Conductivity μscm^{-1}	279	267	132	123	378	232	393	291
		TDS ppm	140	134	66	62	189	116	197	146
		Tempt. ^0c	14.7	18.8	14.6	20	15	19.3	14.9	18.9
Arongtsubo lower	U-7	P^H	7.04	7.14	7.15	7.21	7.18	7.21	7.11	7.17
		Conductivity μscm^{-1}	300	287	159	165	357	335	369	222
		TDS ppm	150	144	80	83	178	168	185	111
		Tempt. ^0c	15	18.7	15	19.5	14.6	18.8	15	20.1
Anerangtsubo central	U-8	P^H	6.78	6.87	6.73	6.76	6.29	6.31	6.48	6.34
		Conductivity μscm^{-1}	381	276	345	321	623	445	691	699
		TDS ppm	191	138	173	161	312	223	346	350
		Tempt. ^0c	14.7	18.7	15.2	19.4	14.7	20.1	15	19.5
Anerangtsubo upper	U-9	P^H	6.81	6.87	6.64	6.46	6.08	6.23	6.57	6.50
		Conductivity μscm^{-1}	387	269	387	328	631	656	701	654
		TDS ppm	194	135	194	164	315	328	351	321
		Tempt. ^0c	15	19.2	14.8	18.9	14.7	18.6	15.1	19.7
Anerangtsubo lower	U-10	P^H	6.68	6.76	6.68	6.86	6.38	6.83	6.65	6.76
		Conductivity μscm^{-1}	378	356	391	343	623	567	692	555
		TDS ppm	189	178	196	172	312	284	346	278
		Tempt. ^0c	14.5	19.5	14.7	19.4	15	19.2	15.1	19.7
Sujentsubo (s/w) site-I	U-11	P^H	7.43	7.55	7.39	7.43	7.53	7.50	7.49	7.51
		Conductivity μscm^{-1}	412	421	597	565	909	873	899	787
		TDS ppm	206	211	298	283	454	437	449	393
		Tempt. ^0c	14.7	18.8	15	19	15	18.8	15	20

Table: 5.1.4.3. Ungma village under Mokokchung district.

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Sujentsubo (n/w) site-Ii	U-12	P^H	7.41	7.43	7.47	7.54	7.50	7.65	7.44	7.48
		Conductivity μscm^{-1}	423	323	397	329	809	790	807	800
		TDS ppm	212	162	199	1165	405	395	404	400
		Tempt. ^0c	14	19.2	14.5	18.9	14.6	19.3	15	21
Tsupjutsubo lower sample-I	U-13	P^H	7.46	7.24	7.14	7.11	6.36	6.63	6.52	6.55
		Conductivity μscm^{-1}	391	254	392	311	686	456	474	367
		TDS ppm	126	127	196	156	342	228	237	184
		Tempt. ^0c	14.2	18	14	17.8	14.3	18.4	15	22
Tsupjutsubo site-II(s/w)	U-14	P^H	7.23	7.32	7.31	7.23	6.96	6.99	6.65	6.76
		Conductivity μscm^{-1}	421	388	432	332	643	634	474	367
		TDS ppm	211	194	216	166	322	317	237	184
		Tempt. ^0c	14.3	18.2	14.4	19.1	14.8	20	15.2	21.1
Aosubatsubo lower-I	U-15	P^H	6.62	6.76	6.97	6.93	6.75	6.65	6.67	6.65
		Conductivity μscm^{-1}	800	821	827	768	833	757	859	825
		TDS ppm	401	412	413	384	417	379	430	413
		Tempt. ^0c	14	18.5	14.7	17.7	15	18.9	15.3	20.5
Aosubatsubo lower-II	U-16	P^H	6.76	6.66	6.69	6.93	6.86	6.95	6.77	6.87
		Conductivity μscm^{-1}	811	760	812	782	732	698	789	656
		TDS ppm	406	380	406	391	366	349	395	328
		Tempt. ^0c	14.6	17.9	15	18	15	21	14.9	20.4
Baputsubo	u-17	P^H	6.58	6.83	6.67	6.86	6.28	6.34	6.56	6.65
		Conductivity μscm^{-1}	422	352	398	400	531	546	601	566
		TDS ppm	211	176	199	200	266	273	300	284
		Tempt. ^0c	14.7	18.7	14.6	18.6	14.5	20	14.9	21

Table: 5.1.5.1.Lumami under Zunheboto district.

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Lumami campus near chemistry dept.	*L-1*	P^H	7.10	7.12	7.23	7.46	7.42	7.34	7.32	7.33
		Conductivity μscm^{-1}	252	167	223	187	172	167	182	177
		TDS ppm	129	84	126	94	96	84	96	86
		Tempt. ^0c	15.7	19.6	15	20	14.8	18.9	15	20
Post gradute women hostel,lumami	*L-2*	P^H	7.34	7.46	7.37	7.44	7.33	7.37	7.58	7.37
		Conductivity μscm^{-1}	426	343	389	356	454	377	482	428
		TDS ppm	208	172	195	178	227	189	223	214
		Tempt. ^0c	15	19.7	15.6	21	14.6	18.6	15	21.5
Post gradute men hostel,Lumami Site-I	*L-3*	P^H	7.23	7.32	7.35	7.33	7.31	7.35	7.32	7.32
		Conductivity μscm^{-1}	188	145	236	254	161	261	282	276
		TDS ppm	144	73	119	127	81	130	146	138
		Tempt. ^0c	15.4	18.9	15.3	20.8	14.8	19.2	15.7	22
Post gradute men hostel,lumami Site-II	*L-4*	P^H	7.11	7.21	7.29	7.24	7.13	7.23	7.22	7.29
		Conductivity μscm^{-1}	254	231	254	199	269	261	278	298
		TDS ppm	127	116	127	100	135	131	139	149
		Tempt. ^0c	14.6	19.6	15.6	20.6	14.7	19.4	15.3	21.3
Lumami (s/w) Before reaching campus	*L-5*	P^H	7.15	7.21	7.15	7.22	7.27	7.34	7.36	7.43
		Conductivity μscm^{-1}	231	198	239	212	276	268	292	154
		TDS ppm	116	99	116	106	138	134	146	77
		Tempt. ^0c	15.7	20	15.3	20.2	14.9	18.9	15.3	20.6
Lumami (N/w) Before reaching campus	*L-6*	P^H	7.24	7.20	7.42	7.35	7.36	7.31	7.36	7.33
		Conductivity μscm^{-1}	281	189	281	208	265	223	272	227
		TDS ppm	141	95	141	104	133	112	136	114
		Tempt. ^0c	15	19.6	15.2	21	14.8	19.3	15.3	21

Table: 5.1.6.1. Tuensang

Sources	Code	Parameters	Year & season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Old medical colony, Tuensang Site-I	*T-1*	P^H	6.66	6.73	6.68	6.83	6.86	6.87	6.73	6.77
		Conductivity μscm^{-1}	548	456	543	485	602	567	556	504
		TDS ppm	274	228	272	243	300	284	278	252
		Tempt. ^0c	14.6	19.8	15	20	14.9	18.9	13.9	18.9
Old medical colony, Tuensang Site-II	*T-2*	P^H	6.59	6.72	6.68	6.78	6.75	6.87	6.69	6.79
		Conductivity μscm^{-1}	432	367	543	567	567	433	587	598
		TDS ppm	216	184	272	283	284	216	294	299
		Tempt. ^0c	15	19.7	14.9	19.9	14	18.3	14.3	19
Chenyongsi colony, St. john sector 'A' Tuensang site-I	*T-3*	P^H	6.76	6.87	6.70	6.67	6.78	6.90	6.74	6.84
		Conductivity μscm^{-1}	546	654	602	467	587	632	591	546
		TDS ppm	273	327	301	234	294	316	296	273
		Tempt. ^0c	14.7	18.9	15	19.7	14.2	18.8	14.4	18.6
Chenyongsi colony, St. john sector 'A' Tuensang site-II	*T-4*	P^H	6.55	6.65	6.75	6.83	6.91	6.97	6.78	6.97
		Conductivity μscm^{-1}	589	606	592	479	622	609	612	598
		TDS ppm	294	303	296	240	311	304	306	299
		Tempt. ^0c	14.8	17.9	14.8	18.9	13.9	20	14	17.8
Tuensang town site-1	*T-5*	P^H	6.88	6.85	6.78	6.81	6.96	6.90	6.77	6.76
		Conductivity μscm^{-1}	479	456	488	413	532	498	491	388
		TDS ppm	240	228	244	207	256	249	246	194
		Tempt. ^0c	15	18.7	15	18.7	14	18.4	13.7	18.2

Table: 5.1.7.1. Tseminyu Sub-division under Kohima district

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Tseminyu Site-1	R-1	P^H	6.02	6.11	6.12	6. 20	6.14	6.21	6.19	6.22
		Conductivity μscm^{-1}	79.6	55	89.6	88	89	77	99.6	96
		TDS ppm	39.8	28	49.8	44	49	39	49.8	48
		Tempt. ^0c	14.6	21	15	18.8	14.8	20	14.7	21
Teseminyu Site-II	R-2	P^H	6.73	6.78	6.72	6.77	6.48	6.84	6.77	6.71
		Conductivity μscm^{-1}	77.1	67	85	64	79	80	91	86
		TDS ppm	34.8	34	43.5	32	39	40	46	43
		Tempt. ^0c	14.6	20.4	15	19	15	21	14.7	20.8
Tseminyu Site-III	R-3	P^H	6.87	6.69	6.76	6.77	6.78	6.84	6.78	6.73
		Conductivity μscm^{-1}	75	69.8	87	90	89	91	86	70
		TDS ppm	38	31.8	43	45	45	46	43	35
		Tempt. ^0c	14.7	20.5	14.9	20.1	15	20.3	15	21
Tseminyu Site-IV	R-4	P^H	6.83	6.78	6.79	6.91	6.83	6.88	6.78	6.87
		Conductivity μscm^{-1}	62.6	66	76	71.6	81	65	77	65
		TDS ppm	31.3	33	38	37	41	33	39	33
		Tempt. ^0c	15.2	21.2	14.6	20.3	14.8	20.7	14.7	20.6
Tseminyu Highway spring well constructed	R-5	P^H	6.92	6.92	6.82	6.86	6.91	6.89	6.83	6.79
		Conductivity μscm^{-1}	179	200	189	99	184	201	197	176
		TDS ppm	89	100	99	50	97	101	99	88
		Tempt. ^0c	14.8	19.8	15	19.4	15	21	15.2	19.5

Table: 5.1.8.1. Wokha

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Wokha Town Near NST	W-1	P^H	5.74	5.77	5.75	5.77	5.76	5.69	5.73	5.76
		Conductivity μscm^{-1}	367	254	349	344	390	289	387	187
		TDS ppm	183.5	127	174.5	172	195	145	194	94
		Tempt. ^0c	14.6	18.7	16.3	21.2	15.7	19.8	14.8	18.7
Highway near Longsa village(public well/spring	W-2	P^H	6.97	6.92	6.98	6.98	6.97	6.96	6.89	6.97
		Conductivity μscm^{-1}	160	123	175	97	179	98	179	108
		TDS ppm	80	62	89	49	89.5	49	89.5	54
		Tempt. ^0c	14.7	18.9	15.7	20.8	15.8	21	14.5	19
Wokha main town near traffic point.	W-3	P^H	6.88	6.89	6.78	6.86	6.91	6.93	6.87	6.89
		Conductivity μscm^{-1}	156	167	185	178	189	220	199	157
		TDS ppm	72	83	93	89	94.5	110	95.5	79
		Tempt. ^0c	14.8	19.1	16	20.7	15.8	19.9	14.6	19.3
Wokha main town near traffic point.	W-4	P^H	6. 88	6. 98	6. 87	6. 72	6.74	6.79	6.78	6.77
		Conductivity μscm^{-1}	176	88	158	212	198	218	199	123
		TDS ppm	88	44	79	106	99	109	100	62
		Tempt. ^0c	14.5	18.8	16.5	21	15.8	20.4	14.3	18
Wokha main gate site-I	W-5	P^H	6.77	6.78	6.88	6.98	6.92	6.99	6.93	6.94
		Conductivity μscm^{-1}	187	154	189	221	201	187	239	213
		TDS ppm	94	77	95	111	101	94	120	107
		Tempt. ^0c	15.2	19.2	15.9	20.7	16	20.5	14.3	18.7

Table: 5.1.8.2. Wokha

Sources	Code	Parameters	Years & Season							
			2005		2006		2007		2008	
			winter	summer	winter	summer	winter	summer	winter	summer
Wokha main gate (s/w)	W-6	P^H	6.72	6.77	6.87	6.74	6.89	6.81	6.68	6.77
		Conductivity μscm^{-1}	216	232	218	121	228	168	239	132
		TDS ppm	108	116	109	61	114	84	120	66
		Tempt. ^0c	13.6	18.6	15	18.9	15.3	19.5	15	20
Wokha NH-61	W-7	P^H	6.79	6.99	6.88	6.75	6.76	6.83	6.76	6.92
		Conductivity μscm^{-1}	216	154	218	254	219	213	299	121
		TDS ppm	108	77	110	127	110	107	149	61
		Tempt. ^0c	13.9	18	14.6	18.5	15	19.4	15	20.2
Wokha main gate (N/w)	W-8	P^H	6.71	6.88	6. 87	6. 81	6.89	6.66	6.66	6.75
		Conductivity μscm^{-1}	232	244	256	167	268	256	259	233
		TDS ppm	116	122	128	84	134	128	130	117
		Tempt. ^0c	14.2	18.3	14.4	18.7	14.8	19.5	15.3	20.2

fig 10. A public well at Wokha town

fig 11. A spring near Tseminyu

fig 12. A mini water tank at NH-39

5.2. Trace Elements observation

A large number of spring and well water sources from different districts of Nagaland were identified and samples was collected during winter (January-March) and summer (June-August) starting from January 2005 to July 2008 for four continuous years. The samples was collected from 20-30 sources each from seven districts (Kohima, Dimapur, Mokokchung, Tuensang, Wokha, Lumami under Zunheboto, Tseminyu and Ungma) for every season covering mainly the urban area of Nagaland.

The water sample collected in a clean plastic container of 1litre and was added with 5 ml of concentrated hydrochloric acid to acidify the sample to pH 2.0 so as to minimize adsorption of metals on the container walls [39, 46]. The volume of the sample was concentrated to 50 ml by evaporating the sample over the hot plate at 70^0 C - 80^0 C for 10-12 hours. The sample was analyzed by Atomic Absorption Spectrometry (AAS) using different analytical wave lengths.

The results of the experimental observation of trace elements of representative samples are given in the following tables (Table no.5.2.1.1. to 5.2.8.1).

5.2: Result of the trace elemental analysis of spring and well water in Nagaland

Table: 5.2.1.1. Mokokchung

Sl. no	Samples	Code	As	Ag	Cu	Fe	Pb	Cd	Zn	Ni	Mn	Ca	Mg
1	*Sangtemla ward mandir well site-I*	*m-1*	0.001	ND	0.02	0.04	0.15	ND	0.80	0.002	0.06	1.61	0.17
2	*Sangtemla ward site-II*	*m-2*	0.001	0.001	0.01	0.05	0.14	0.001	0.78	0.001	0.04	2.01	0.20
3	*Sangtemla ward site-III*	*m-3*	0.001	ND	0.02	0.04	0.15	ND	0.86	0.003	0.05	1.87	0.17
4	*Aongza ward site-I*	*m-4*	0.001	ND	0.05	0.09	0.03	ND	0.27	0.00	0.04	1.33	2.28
5	*Aongza ward site-II*	*m-5*	ND	ND	0.06	0.11	0.03	ND	0.31	0.001	0.05	2.03	2.11
6	*Aongza ward site-III*	*m-6*	0.001	ND	0.05	0.10	0.02	ND	0.29	0.000	0.04	2.00	2.19
7	*Arkong ward site-I*	*m-7*	0.001	ND	0.03	0.09	0.01	0.001	0.32	0.000	0.14	1.78	2.12
8	*Arkong ward site-II*	*m-8*	ND	0.001	0.04	0.11	0.01	0.001	0.41	0.000	0.21	2.18	1.91
9	*Arkong ward site-III*	*m-9*	0.001	ND	0.03	0.09	0.01	ND	0.37	0.000	0.16	1.87	2.01
10	*Dilong ward toward new market site-I*	*m-10*	0.001	0.001	0.05	0.09	0.12	0.001	3.39	0.002	0.02	1.18	0.93

Table: 5.2.1.2. Mokokchung

Sl. no	Samples	Code	As	Ag	Cu	Fe	Pb	Cd	Zn	Ni	Mn	Ca	Mg
11	*Dilong ward below town hall site-II*	*m-11*	0.001	ND	0.47	0.14	0.05	0.001	0.82	0.00	0.41	3.88	1.61
12	*Dilong ward site-III*	*m-12*	0.001	0.001	0.25	0.09	0.12	0.001	3.01	0.001	0.32	1.34	0.97
13	*Penli ward DC Hill upper (n/w)*	*m-13*	ND	0.003	0.14	0.22	0.06	0.001	0.94	0.00	0.33	0.75	1.11
14	*Penli ward DC Hill upper well site-I*	*m-14*	ND	0.002	0.16	0.25	0.08	0.001	0.87	0.003	0.21	0.84	1.23
15	*Penli ward below DC office lower site-II*	*m-15*	0.002	ND	0.04	0.24	0.22	ND	0.34	0.002	0.32	0.45	2.11
16	*Penli ward lower well khasilane*	*m-16*	0.001	ND	0.06	0.22	0.17	ND	0.35	0.002	0.29	0.48	2.32

ND: *Not detected*
All concentration in *mg/L*

Table: 5.2.2.1. Ungma village under Mokokchung

Sl. no	Samples	Code	As	Ag	Cu	Fe	Pb	Cd	Zn	Ni	Mn	Ca	Mg
1	*Sericulture farm upper*	*u-1*	0.002	0.001	0.02	0.10	0.09	0.001	0.54	0.001	0.07	2.92	1.30
2	*Sericulture farm lower*	*u-2*	0.001	ND	0.02	0.15	0.11	0.001	0.67	0.002	0.11	3.12	1.12
3	*Tsusenyongupper*	*u-3*	0.001	ND	0.06	0.45	0.04	ND	0.99	0.000	0.08	4.66	1.58
4	*Tsusenyong lower*	*u-4*	0.001	0.001	0.10	0.47	0.06	ND	0.89	0.000	0.11	4.76	2.19
5	*Arongtsubo (upper)*	*u-5*	ND	ND	0.03	0.06	0.06	ND	0.13	0.001	0.01	0.94	0.64
6	*Arongtsubo (lower)*	*u-6*	0.001	ND	0.05	0.09	0.03	0.001	0.27	0.000	0.04	1.33	2.28
7	*Arongtsubo east*	*u-7*	0.001	0.001	0.04	0.07	0.06	0.001	0.17	0.000	0.03	1.13	1.83
8	*Anerangtsubo central*	*u-8*	ND	0.002	0.04	0.17	0.06	ND	0.31	0.000	0.05	1.21	1.97
9	*Anerangtsubo upper*	*u-9*	ND	0.002	0.06	0.19	0.07	ND	0.39	0.001	0.05	2.11	1.63
10	*Anerangtsubo lower*	*u-10*	0.001	0.003	0.07	0.21	0.08	0.001	0.43	0.002	0.11	2.01	1.77

Table: 5.2.2.2. Ungma village under Mokokchung.

Sl. no	Samples	Code	As	Ag	Cu	Fe	Pb	Cd	Zn	Ni	Mn	Ca	Mg
11	*Sujentsubo (s/w) site-I*	*u-11*	0.002	0.001	0.03	0.06	0.06	ND	0.34	ND	0.03	9.88	2.26
12	*Sujentsubo (s/w) site-I*	*u-12*	0.001	0.002	0.06	0.09	0.05	ND	0.43	ND	0.04	10.23	2.45
13	*Tsupjutsubo lower-I*	*u-13*	ND	0.001	0.02	0.67	0.14	0.001	0.17	0.002	0.08	0.81	1.64
14	*Tsupjutsubo site-II(s/w)*	*u-14*	ND	0.001	0.03	0.71	0.15	0.001	0.21	0.002	0.07	0.98	1.81

ND: *Not detected*
All concentration in *mg/L*

Table: 5.2.3.1 Kohima

Sl. no	Samples	Code	As	Ag	Cu	Fe	Pb	Cd	Zn	Ni	Mn	Ca	Mg
1	*Jotsoma gate Sc. college road*	*k-1*	ND	ND	0.02	0.21	0.07	0.001	0.17	0.001	0.02	1.31	1.74
2	*CNBC office Sc. college road*	*k-2*	0.002	0.001	0.02	0.48	0.01	ND	0.11	ND	0.13	2.97	1.24
3	*Lower chandmari-AG road*	*k-3*	0.001	0.001	0.06	0.71	0.05	ND	0.10	ND	0.13	11.0	2.57
4	*Upper chandmari public well*	*k-4*	0.001	0.001	0.04	0.76	0.04	ND	0.17	ND	0.17	22.0	2.34
5	*Midlane public well*	*k-5*	0.001	0.001	0.13	0.09	0.14	0.001	0.11	0.002	ND	8.42	2.78
6	*Water fetch for Kohima,Highway-39 (before check gate)*	*k-6*	ND	ND	0.04	0.08	0.04	0.001	0.08	ND	0.04	3.14	1.25
7	*Garbage dumping area*	*k-7*	0.001	0.001	0.07	0.07	0.16	0.002	0.12	0.003	0.14	5.68	3.25
8	*Dte. Printing press area*	*k-8*	0.001	0.001	0.03	0.10	0.11	0.001	0.12	0.002	0.06	2.68	1.25
9	*Chandmari-AG road Near transformer*	*k-9*	ND	ND	0.05	0.08	0.06	0.001	0.06	ND	0.04	3.45	1.25
10	*PWD public well*	*k-10*	0.001	ND	0.04	0.03	ND	ND	0.04	ND	0.03	2.67	1.45
11	*Chandmari-Midland boundary*	*K-11*	0.001	0.001	0.16	0.09	0.14	ND	0.11	0.002	ND	5.46	2.43

Table: 5.2.3.2. Kohima

Sl. no	Samples	Code	As	Ag	Cu	Fe	Pb	Cd	Zn	Ni	Mn	Ca	Mg
12	*AG colony facing Chandmari*	*K-12*	0.001	0.001	0.03	0.29	0.04	0.001	0.10	ND	0.02	2.27	2.61
13	*NH-39 Near mezoma village*	*K-13*	ND	0.001	0.92	0.58	0.02	ND	0.88	ND	0.03	0.42	3.01
14	*Lerie colony Upper*	*K-14*	0.001	0.001	0.03	0.05	0.09	0.001	0.07	0.001	0.03	0.57	2.65
15	*Lerie site-II*	*K-15*	0.001	0.001	0.02	0.15	0.04	0.001	0.05	ND	0.03	1.23	3.26
16	*Lerie colony site-III*	*K-16*	ND	0.001	0.03	0.06	0.08	0.001	0.10	0.001	0.04	1.57	2.07
17	*Forest colony site-I (N/W)*	*k-17*	ND	0.001	0.03	0.37	0.01	ND	0.17	ND	0.13	3.02	1.24
18	*Forest colony site-I(N/W)*	*k-18*	0.001	0.001	0.02	0.45	0.02	ND	0.21	0.002	0.15	2.89	1.13
19	*Agri colony site-I*	*k-19*	0.001	ND	0.02	0.44	0.01	0.001	0.19	0.001	0.14	2.79	1.14
20	*Upper chandmari public well-II*	*k-20*	0.001	ND	0.05	0.83	0.03	0.001	0.16	0.001	0.17	19.01	2.12
21	*Midlane site-II*	*k-21*	0.001	0.001	0.11	0.08	0.16	0.001	0.13	0.003	ND	9. 24	2.89
22	*Agri colony upper-II*	*k-22*	ND	ND	0.02	0.38	0.01	0.001	0.17	0.001	0.13	2.77	1.21

ND: *Not detected* All concentration in *mg/L*

Table: 5.2.4.1. Lumami, Zunheboto District

Sl. no	Samples	Code	As	Ag	Cu	Fe	Pb	Cd	Zn	Ni	Mn	Ca	Mg
1	*Lumami campus chem.dept*	*L-1*	0.001	ND	0.06	0.21	0.11	ND	0.39	0.001	0.14	9.98	0.89
2	*Post graduate women hostel, Lumami*	*L-2*	ND	0.001	0.08	0.18	0.10	ND	0.45	0.001	0.12	10.97	0.82
3	*Post graduate women hostel, Lumami site-I*	*L-3*	ND	0.001	0.07	0.17	0.12	ND	0.41	0.001	0.12	10.11	1.02
4	*Post graduate men hostel, Lumami*	*L-4*	0.002	ND	0.04	0.02	0.03	ND	0.78	ND	0. 12	18.53	3.24
5	*Post graduate men hostel Lumami site-II*	*L-5*	ND	0.001	0.04	0.03	0.02	ND	0.88	ND	0.11	16.13	2.84

ND: *Not detected*
All concentration in *mg/L*

Table: 5.2.5.1. Dimapur

Sl. no	Samples	Code	As	Ag	Cu	Fe	Pb	Cd	Zn	Ni	Mn	Ca	Mg
1	*6th mile*	*D-1*	ND	0.001	0.08	0.24	0.08	0.001	0.45	0.001	0.12	1.22	2.56
2	*Half nagarjan*	*D-2*	0.002	ND	0.05	0.37	0.03	0.001	0.78	ND	0.11	3.23	3.23
3	*Naga Cemetry colony*	*D-3*	ND	0.001	0.07	0.68	ND	0.001	0.45	ND	0.09	1.57	2.10
4	*Signal colony*	*D-4*	0.001	ND	0.04	0.32	ND	0.001	1.88	ND	0.21	3.50	1.60
5	*Dubagon brick factory*	*D-5*	0.001	0.001	0.07	0.07	0.04	0.002	0.45	Nd	0.07	6.73	3.33
6	*Dubagon site-II*	*D-6*	0.002	0.001	0.06	0.11	ND	0.001	0.48	0.001	0.08	0.75	2.45
7	*7th mile Lpg refilling centre*	*D-7*	ND	0.001	0.08	0.22	0.03	0.001	0.45	ND	0.09	0.18	1.32
8	*Signal-Duncan*	*D-8*	0.001	ND	0.04	0.02	0.05	0.001	1.78	0.001	0.11	2.86	2.48
9	*Padumpukri site-I*	*D-9*	0.001	0.001	0.05	0.10	ND	ND	0.65	ND	0.12	1.96	3.07
10	*Padumpukri site-II*	*D-10*	0.001	ND	0.04	0.24	0.06	ND	0.68	ND	0.11	0.09	1.27

ND: *Not detected*
All concentration in *mg/L*

Table: 5.2.5.2. Dimapur

Sl. no	Samples	Code	As	Ag	Cu	Fe	Pb	Cd	Zn	Ni	Mn	Ca	Mg
11	*3th mile site-I*	*D-11*	ND	0.001	0.10	0.33	0.07	0.001	0.47	0.001	0.19	2.22	2.95
12	*3th mile site-II*	*D-12*	0.001	0.001	0.07	0.27	0.04	0.002	0.39	0.001	0.09	6.73	3.41
13	*Kushibill site-II*	*D-14*	ND	0.001	0.09	0.68	0.02	0.001	0.37	0.001	0.12	2.57	1.14
14	*Purana bazaar site-I*	*D-18*	0.001	0.001	0.05	0.17	0.01	ND	0.61	ND	0.17	2.91	3.07
15	*Purana bazaar site-III*	*D-20*	0.002	0.001	0.06	0.21	ND	0.001	0.39	ND	0.09	1.75	1.32
16	*PWD site-I*	*D-21*	0.002	ND	0.05	0.41	0.03	0.001	0.67	ND	0.11	4.12	3.23
17	*Duncan site-I*	*D-23*	0.001	ND	0.04	0.32	0.05	0.001	1.78	0.001	0.11	2.86	2.48
18	*5th mile site-I*	*D-26*	ND	0.001	0.08	0.22	0.03	0.001	0.45	0.001	0.11	2.18	1.41
19	*Signal colony site-III*	*D-28*	0.001	ND	0.04	0.39	0.01	0.001	1.68	ND	0.21	3.55	1.63
20	*Padumkhari site-III*	*D-30*	0.001	ND	0.03	0.54	0.06	ND	0.63	ND	0.11	1.32	1.23

Table: 5.2.6.1 Wokha

Sl. no	Samples	Code	As	Ag	Cu	Fe	Pb	Cd	Zn	Ni	Mn	Ca	Mg
1	*Wokha Town Near NST*	*W-1*	0.001	0.001	0.08	0.18	0.08	0.001	0.17	ND	0.05	1.97	3.82
2	*Public well/spring near longsa village*	*W-2*	ND	ND	0.07	0.20	0.14	ND	0.08	0.001	0.05	1.53	1.24
3	*Near traffic point Site-I*	*W-3*	0.001	0.001	0.06	0.10	0.06	ND	0.07	0.001	0.04	1.97	2.82
4	*Near traffic point Site-II*	*W-4*	0.001	ND	0.05	0.19	0.05	ND	0.06	0.001	0.04	2.17	1.98
5	*Main gate site-I*	*W-5*	0.001	0.001	0.06	0.21	0.05	ND	0.06	0.001	0.04	1.87	2.12
6	*Wokha main gate(s/w)*	*W-6*	ND	0.001	0.06	0.17	0.05	0.001	0.06	ND	0.05	2.59	1.82
7	*Wokha NH-61*	*W-7*	0.001	ND	0.07	0.23	0.14	ND	0.08	0.002	0.05	2.45	1.54

ND: *Not detected*
All concentration in *mg/L*

Table: 5.2.7.1 Tseminyu

Sl. no	Samples	Code	As	Ag	Cu	Fe	Pb	Cd	Zn	Ni	Mn	Ca	Mg
1	*Tseminyu Site-I (n/w)*	*R-1*	ND	0.001	0.08	0.21	0.05	ND	0.09	ND	0.05	3.21	1.02
2	*Tseminyu Site-II (s/w)*	*R-2*	0.001	ND	0.04	0.19	0.07	ND	0.08	0.001	0.05	2.63	1.21
3	*Tseminyu site-III middle*	*R-3*	ND	0.001	0.07	0.24	0.05	0.001	0.06	ND	0.05	3.21	1.12
4	*Tseminyu site-IV*	*R-4*	ND	ND	0.04	0.19	0.06	ND	0.07	ND	0.05	2.76	1.05
5	*Highway spring/well constructed*	*R-5*	0.001	0.001	0.06	0.26	0.08	0.001	0.18	0.001	0.04	3.17	2.52

ND: *Not detected*
All concentration in *mg/L*

Table: 5.2.8.1 Tuensang

Sl. no	Samples	Code	As	Ag	Cu	Fe	Pb	Cd	Zn	Ni	Mn	Ca	Mg
1	*Old medical colony, tuensang site-I upper*	*T-1*	ND	0.001	0.07	0.18	0.04	0.001	0.07	0.001	0.04	3.91	1.82
2	*Old medical colony, tuensang lower site-II*	*T-2*	ND	0.001	0.05	0.21	0.04	0.001	0.05	0.001	0.04	3.69	1.68
3	*Chenyongsi colony, st. john sector 'A' tuensang site-I*	*T-3*	ND	ND	0.06	0.14	0.03	ND	0.08	ND	0.05	2.73	1.24
4	*Chenyongsi colony, st. john sector 'A' tuensang site-II*	*T-4*	ND	ND	0.07	0.17	0.03	ND	0.07	ND	0.05	2.76	0.98
5	*Tuensang main town*	*T-5*	0.001	ND	0.06	0.28	0.04	0.001	0.07	ND	0.04	4.97	2.82

ND: *Not detected*
All concentration in *mg/L*

5.3. Average and comparative concentration of physiochemical characteristics & trace elements in water samples.

The experimental observation of the average concentration of physiochemical characteristics was calculated and is given in table 5.3.1. Similarly the average concentration for trace elements of the representative water samples was calculated and is given in the table no 5.3.2. The minimum and maximum concentration of trace elements and yearly wise comparative physiochemical characteristics of water sample is given in the table no 5.3.4, 5.3.5 & 5.3.6. The season wise comparative physiochemical characteristic of water sample is also given in the table no.5.3.7 and 5.3.8.

5.3. Average & comparative data of physiochemical characteristics & Trace elements.

Table: 5.3.1. Average value of physiochemical characteristics in water samples Nagaland.

Parameters	Units	Standards	DISTRICT HEADQUARTERS/SUB-DIVISION							
			Kohima	Dimapur	Mokokchung	Wokha	Tuensang	Lumami,	Tseminyu	Ungma
Colour		Colourless	clear	Slightly turbid	Clear	clear	clear	clear	clear	clear
Water Tempt.	^{0}C	40 (IS 2490-1983)	17	22	19	18.8	17	19.3	18	19
pH		6.0-8.5 WHO	6.45	6.94	6.72	6.56	6.76	7.41	6.68	7.12
Electrical conductivity	µs		763	814	448	569	590	341	94	373
DO	mg/L	8<	16.5	15	16.3	16.5	18	17	16	16
BOD	mg/L	<3	2.8	2.5	2.8	3.0	2.8	2.9	3.0	3.0
COD	mg/L	250(BIS)	87	89	86	85	84	83	89	83
TDS	mg/L	500 USPH	381	407	242	284	235	170	56	186
Total hardness as $CaCO_3$	mg/L	300 (BIS) 10500-1983	39	82	54	58	37	60	41	51
Calcium hardness as Ca^{2+}	mg/L	75 (BIS) 10500-1983	24	40	25	24	21	34	25	28
Magnesium hardness as Mg^{2+}	mg/L	30 (BIS) 10500-1983	15.7	37	18.3	27	16.2	21.8	19.3	19.2

Table: 5.3.2. Average value of trace elements in water samples, Nagaland.

Parameters	Units	Standards	DISTRICT HEADQUARTERS/SUB-DIVISION							
			Kohima	Dimapur	Mokokchung	Wokha	Tuensang	Lumami,	Tseminyu	Ungma
Arsenic	mg/L	0.01 (WHO)	0.001	0.002	0.001	0.001	0.001	0.001	ND	0.001
Silver	mg/L	0.05	0.001	0.001	0.001	ND	ND	ND	ND	0.001
Copper	mg/L	0.05 (BIS)10500-1983	0.16	0.06	0.13	0.05	0.05	0.06	0.05	0.03
Lead	mg/L	0.1 (BIS) 10500-1983	0.08	0.08	0.14	0.08	0.03	0.06	0.06	0.07
Zinc	mg/L	5.0 (WHO)	0.20	3.13	1.01	0.10	0.10	0.71	0.07	0.4
Nickel	Mg/L	0.02 (WHO)	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.002
Iron	mg/L	0.3 (WHO)	0.32	0.36	0.34	0.25	0.19	0.1	0.15	0.3
Cadmium	mg/L	0.003 (WHO)	0.002	0.003	0.002	0.002	0.002	0.001	0.001	0.001
Manganese	mg/L	0.1 (WHO)	0.04	0.12	0.11	0.05	0.04	0.12	0.05	0.06
Calcium	mg/ L	75-200 ICMR	3.02	7.03	1.53	1.55	3.5	6.75	3.0	3.11

Table: 5.3.3. Physiochemical characteristics of water samples in Nagaland

DISTRICT HEADQUARTERS /SUB-DIVISION	POPULATION (PERSONS) SOURCES: CENSUS OF 2001	pH	CONDUCTIVITY μSCM^{-1}	TDS (PPM and mg/l	WATER TEMPT. (^0C)	DO mg/l	BOD mg/l	COD mg/l	TOTAL HARDNESS as $CaCO_3$ mg/l
Kohima	314366	5.56-7.23	60-1380	31-612	13.6-21	10-23	2.1-3.7	78-87	32.9-44.3
Mokokchung	227230	6.65-7.42	120-912	60-461	14.6-22	9.5-22	2.2-3.8	82-90	42.0-65.3
Dimapur	308382	6.52-7.23	241-1820	122-910	15.6- 24	6.9-19	1.8-3.2	89-98	43.4-120.3
Tuensang	414801	6.68-7.02	548-632	279-318	13.5-22	11-25	2.9-3.7	78-84	42.0-76.3
Wokha	161098	6.31-6.67	446-569	229-284	15-21	8.9-24	2.8-3.7	76-85	46.1-68.3
Tseminyu	54212	6.02-6.83	63-72	32-39.6	15-22	8.3-23	2.5-3.9	71-84	32.9-48.9
Lumami, Zunheboto	154909	7.24-7.66	123-454	64-232	15-23	10-24	2.5-3.8	73-83	42.0-76.3
Ungma	10000	6.36-7.56	121-909	61 -450	14.5-23	8.2-24	2.7-3.8	73-83	32.0-69.5

Table 5.3.4. Minimum and maximum concentration of trace elements in water samples Nagaland

sl. no.	DISTRICT	Ag	As	Cu	Fe	Pb	Cd	Mn	Zn	Ni	Ca	Mg
1	Kohima	0.00-0.001	0.00-0.002	0.03-0.92	0.05-0.58	0.02-0.14	0.00-0.002	0.00-0.13	0.06-0.88	0.01-0.003	0.42-8.00	1.24-3.01
2	Dimapur	0.00-0.001	0.001-.002	0.04-0.08	0.06-0.68	0.05-0.14	0.001-.004	0.03-0.16	0.12-3.88	0.01-0.003	3.42-21.0	1.24-3.01
3	Mokokchung	0.00-0.001	0.00-0.002	0.02-0.47	0.05-0.34	0.03-0.28	0.001-0.002	0.02-0.17	0.27-3.39	0.00-0.002	0.45-4.88	0.93-2.28
4	Wokha	0.00-0.001	0.00-0.001	0.02-0.27	0.05-0.26	0.03-0.14	0.001-0.002	0.02-0.27	0.27-2.39	0.00-0.003	0.67-3.88	0.90-2.29
5	Tuensang	0.00-0.001	0.00-0.001	0.02-0.26	0.05-0.31	0.01-0.04	0.00-0.001	0.02-0.13	0.07-1.89	0.00-0.002	0.67-3.68	0.73-1.89
6	Lumami, Zunheboto	0.00-0.001	0.00-0.002	0.04-0.08	0.02-0.18	0.03-0.10	0.00-0.001	0.12-0.21	0.45-0.78	0.00-0.001	10.97-18.53	0.82-3.24
7	Ungma	0.00-0.002	0.00-0.002	0.02-0.06	0.06-0.67	0.03-0.09	0.001-0.002	0.00-0.18	0.13-0.99	0.01-0.003	0.81-4.66	0.64-2.28
8	Tseminyu	0.00-0.001	0.00-0.001	0.02-0.26	0.06-0.27	0.05-0.09	0.001-0.002	0.02-0.07	0.06-1.99	0.00-0.002	0.83-4.56	0.59-1.28

All concentration in mg/L or ppm

Table: 5.3.5. Comparative data of physiochemical parameters of water samples collected during the years 2005 to 2008 (4 years).

Location	Years	Parameters								
		P^H	EC μscm^{-1}	TDS ppm	DO mg/l	BOD mg/l	COD mg/l	Total hardness mg/l	Calcium hardness as Ca^{2+} mg/l	Magnesium Hardness as Mg^{2+} mg/l
Kohima	2005-06	5.67-6.57	523	262	10-23	1.9-3.3	87	32.4-42.3	17.6-28.8	12.7-17.4
	2006-07	5.64-6.66	607	304	10-23	1.9-3.4	86	32.6-42.3	17.8-28.8	12.8-17.4
	2007-08	5.56-6.62	654	327	9.8-23	2.0-3.4	89	32.9-44.3	17.6-29.8	13.0-18.4
Dimapur	2005-06	6.75-7.31	910	405	7.9-21	1.7-3.2	96	44.4-104.3	21.6-57.8	23.7-51.4
	2005-07	6.88-7.34	844	422	7.9-21	1.7-3.2	101	42.6-106.3	19.6-56.8	19.8-48.4
	2007-08	6.88-7.33	822	410	7.6-19	1.6-3.3	101	43.4-111.3	21.6-58.5	22.0-52.2
Mokokchung	2005-06	6.35-7.28	384	193	10-24	2.3-3.9	82	42.4-64.3	19.6-27.8	16.2-21.4
	2006-07	6.87-7.31	473	236	9.7-24	2.1-3.8	84	41.4-62.3	18.6-29.8	17.0-19.7
	2007-08	6.64-7.12	553	277	9.5-24	2.2-3.8	85	42.00-65.3	18.5-31.6	16.2-20.4
Wokha	2005-06	5.69-6.92	285	142	9-24	2.6-3.9	85	44.4-66.3	18.6-29.8	21.2-31.4
	2006-07	5.68-6.93	290	145	9-24	2.7-3.8	91	47.4-69.4	19.9-29.8	21.5-33.4
	2007-08	5.76-6.92	291	146	8.9-24	2.7-3.8	87	46.1-68.3	17.9-29.2	20.7-33.3
Tuensang	2005-06	6.68-6.70	575	288	10-26	2.8-3.7	84	29.4-43.3	15.6-22.7	12.7-19.4
	2006-07	6.86-6.90	617	309	10-25	2.7-3.7	83	31.1-42.7	14.8-23.9	12.8-19.4
	2007-08	6.73-6.74	579	290	11-25	2.6-3.7	85	29.6-43.1	16.6-23.7	13.0-19.4

Table: 5.3.6. Comparative data of physiochemical characteristics of water samples collected during the years 2005 to 2008 (4years).

Location	Years	Parameters								
		P^H	EC μscm^{-1}	TDS ppm	DO mg/l	BOD mg/l	COD mg/l	Total hardness mg/l	Calcium hardness as Ca^{2+} mg/l	Magnesium Hardness as Mg^{2+} mg/l
Lumami, Zunheboto	2005-06	7.34-7.65	371	185	10.-24	2.4-3.9	83	42.4-74.7	19.6-47.8	16.2-26.4
	2006-07	7.28-7.65	355	178	10-24	2.5-3.8	81	41.4-77.1	18.6-49.8	17.0-28.1
	2006-08	7.28-7.58	358	179	9.4-24	2.4-3.8	81	42.0-76.3	18.5-49.6	16.2-27.4
Tseminyu	2005-06	6.02-6.92	575	287	9-23	2.4-3.9	89	33.4-48.3	19.6-28.8	13.7-17.8
	2006-07	6.07-6.93	617	308	9-23	2.5-3.8	90	32.6-49.3	19.8-29.0	12.8-18.4
	2007-08	6.05-6.90	579	289	8.1-23	2.5-3.8	88	32.9-48.9	18.6-29.8	13.0-19.0
Ungma	2005-06	7.25-7.39	345	173	8.7-24	2.6-3.7	81	32.4-67.3	15.6-37.8	16.2-19.4
	2006-07	7.02-7.91	631	315	8.5-24	2.5-3.7	82	32.7-69.3	18.6-35.8	17.0-21.7
	2007-08	7.17-7.86	537	268	8.2-24	2.5-3.6	81	32.0-69.5	18.5-36.6	16.2-22.4

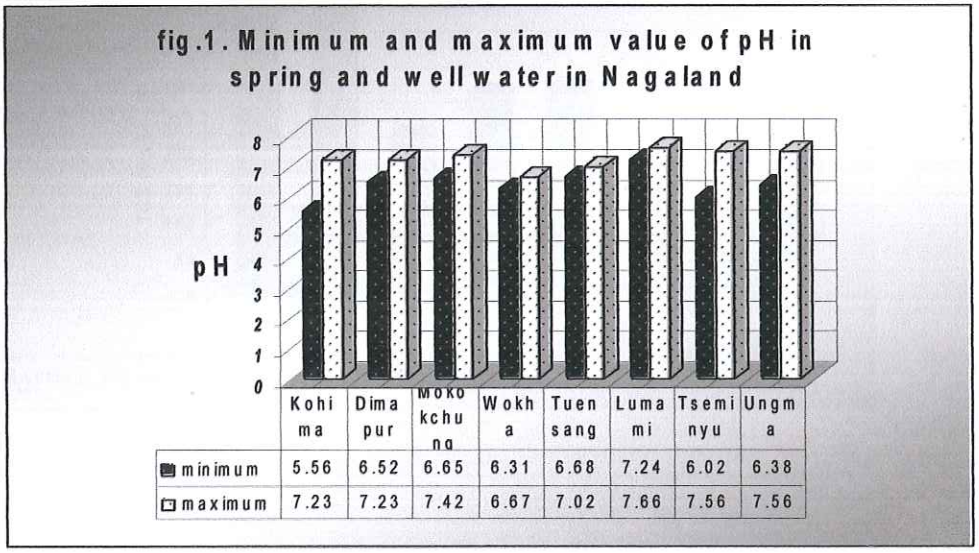
Table: 5.3.7. Physiochemical characteristics of water samples collected in summer and winter seasons

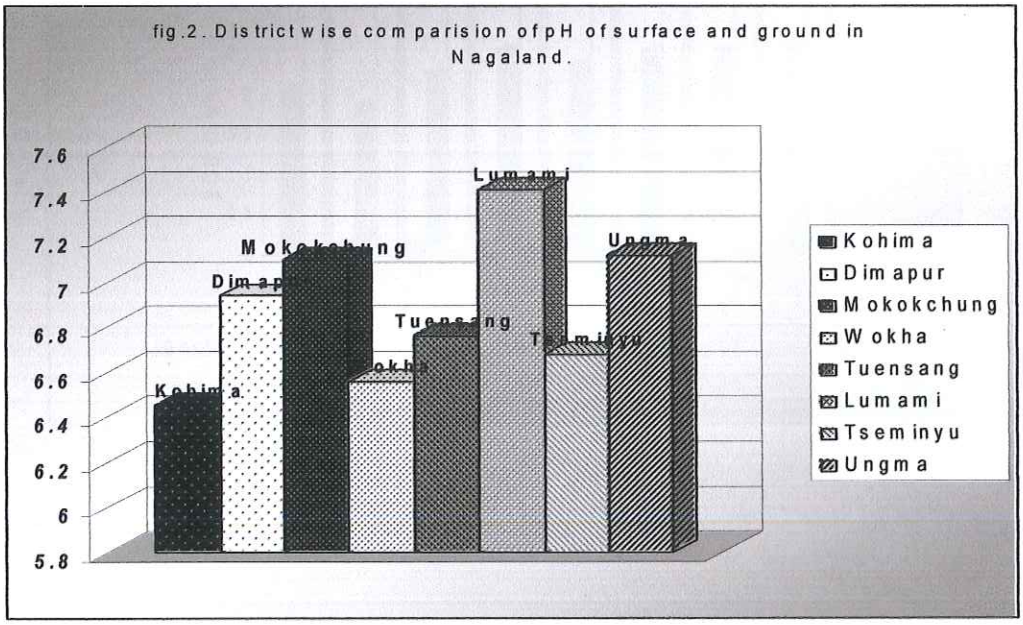
DISTRICTS /SUB-DIVISION Sampling Area	SEASONS	WATER TEMPT. (^{0}C)	pH	CONDUCTIVITY μSCM^{-1}	TDS ppm	DO mg/l	BOD mg/l	TOTAL HARDNESS as CaCO3 mg/l
KOHIMA	SUMMER (Jun-Aug)	16-22	5.57-7. 32	60-1380	31-612	8-21	2.1-3.7	32.9-42.1
	WINTER (JAN-MAR)	13-17	5.56-7.23	77-1311	39-656	10-24	1.6-3.3	34-44.3
MOKOKCHUNG	SUMMER (Jun-Aug)	17-23	6.65-7.42	113-912	60-461	9.5-23	2.2-3.8	42-60.5
	WINTER (JAN-MAR)	14-17	6.64-7.26	120-899	60-450	10-24	2-3.2	42-65.3
DIMAPUR	SUMMER (Jun-Aug)	17-24	6.52-7.23	241-1820	122-910	7.9-21	1.8-3.2	43.4-110
	WINTER (JAN-MAR)	15-21	6.51-7.19	269-1910	135-955	9-21	1.8-3.1	45-121.3
TUENSANG	SUMMER (Jun-Aug)	16-22	6.68-7.02	213-632	279-318	11-23	1.9-3.7	29.6-41.2
	WINTER (JAN-MAR)	13-17	6.58-7.02	256-723	128-362	11-24	1.4-3.6	31-43.1
WOKHA	SUMMER (Jun-Aug)	16-23	6.31-6.67	246-569	229-284	8.9-24	2.8-3.7	44.2-64.9
	WINTER (JAN-MAR)	14-17	6.29-6.57	257-633	129-317	9-24	2.2-3.5	46.1-68.3
TSEMINYU	SUMMER (Jun-Aug)	14-20	6.02-6.83	63-272	32-39.6	8.1-23	2-3.9	31-46.3
	WINTER (JAN-MAR)	14-17	6.02-6.76	64-288	32-144	9-24	1.9-3.9	32.9-48.9

Table: 5.3.8. Physiochemical characteristics of water samples collected in summer and winter seasons

DISTRICTS /SUB-DIVISION Sampling Area	SEASONS	TEMPT. (^{0}C)	pH	CONDUCTIVITY μSCM^{-1}	TDS (PPM and Mg/l)	DO Mg/l	BOD Mg/l	TOTAL HARDNESS as CaCO3 Mg/l
TSEMINYU	SUMMER	15-23	6.02-6.83	63-272	32-39.6	8.1-23	2-3.9	31-46.3
	WINTER	14-19	6.02-6.76	64-288	32-144	9-24	1.9-3.9	32.9-48.9
LUMAMI, ZUNHEBOTO	SUMMER	16-23	7.24-7.66	123-454	64-232	10-26	2.5-3.8	41.3-69.5
	WINTER	15-20	7.12-7.45	144-467	72-234	11-27	2.1-3.8	42.0-76.3
UNGMA	SUMMER	16-22	6.36-7.56	121-909	61 -450	8.2-23	2.7-3.8	32-66.6
	WINTER	14-20	6.35-7.46	201-1070	101-535	9-24	2.6-3.7	34.0-69.5

5.4: EXPERIMENTAL GRAPHS.





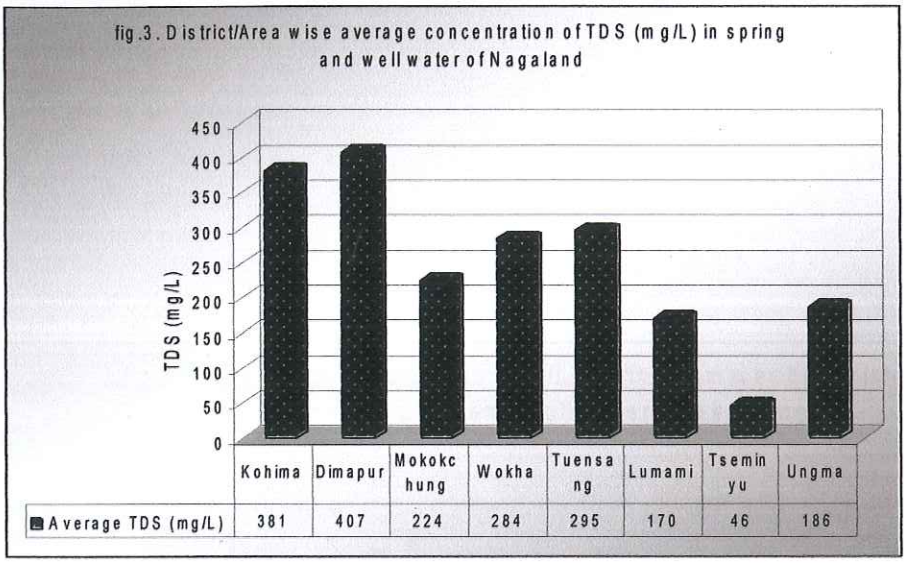


fig.3. District/Area wise average concentration of TDS (mg/L) in spring and well water of Nagaland
TDS (mg/L)
450
400
350
300
250
200
150
100
50
0
Kohima
Dimapur
Mokokchung
Wokha
Tuensang
Lumami
Tseminyu
Ungma
Average TDS (mg/L)
381
407
224
284
295
170
46
186

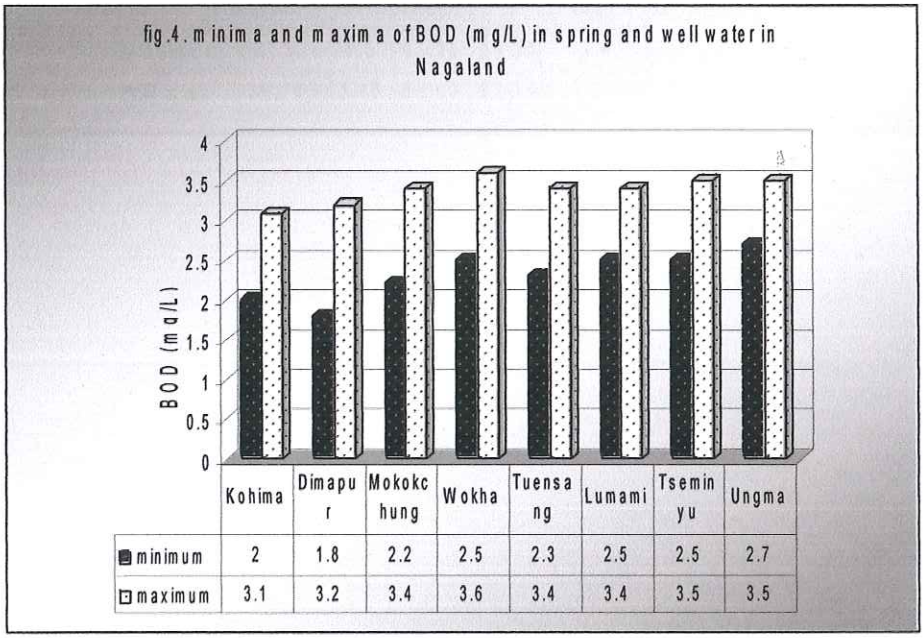
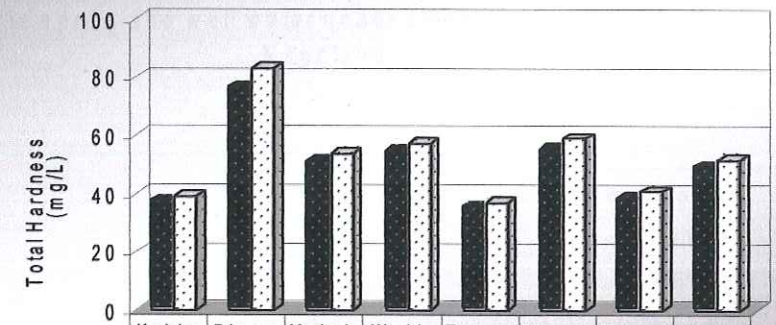


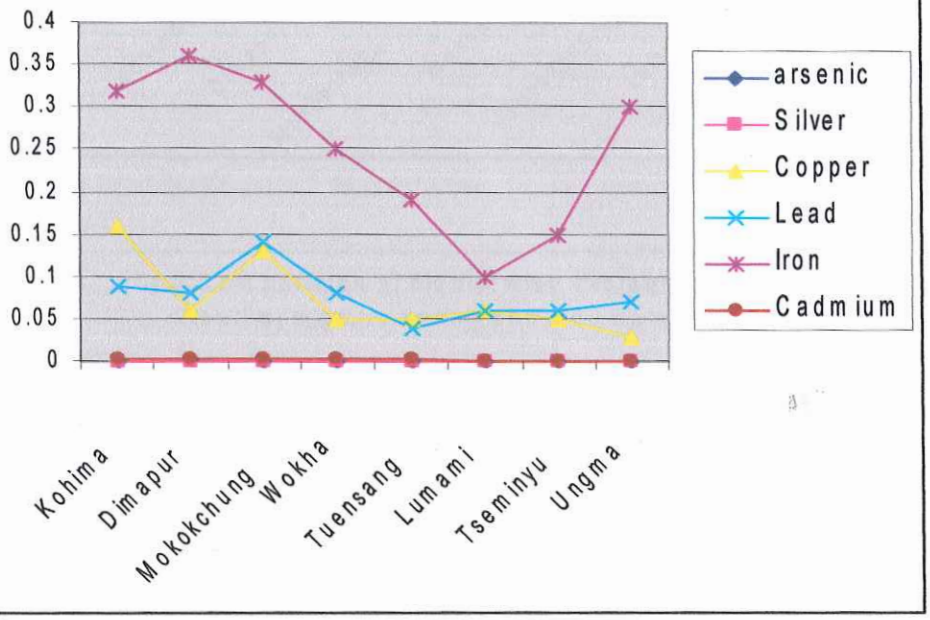
fig.4. minima and maxima of BOD (mg/L) in spring and well water in Nagaland
BOD (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
Kohima
Dimapur
Mokokchung
Wokha
Tuensang
Lumami
Tseminyu
Ungma
minimum
2
1.8
2.2
2.5
2.3
2.5
2.5
2.7
maximum
3.1
3.2
3.4
3.6
3.4
3.4
3.5
3.5

fig.5.Average Total Hardness (mg/L) during summer and winter seasons in spring and well water of Nagaland



	Kohima	Dimapur	Mokokchung	Wokha	Tuensang	Lumami	Tseminyu	Ungma
Summer	37.5	76.5	51.25	54.35	35.4	55.4	38.65	49.3
Winter	39.15	83.15	53.65	57.15	37.05	59.15	40.9	51.75

fig.7 .Average concentration of trace heavy metal elements in spring and well water under different districts of Nagaland.



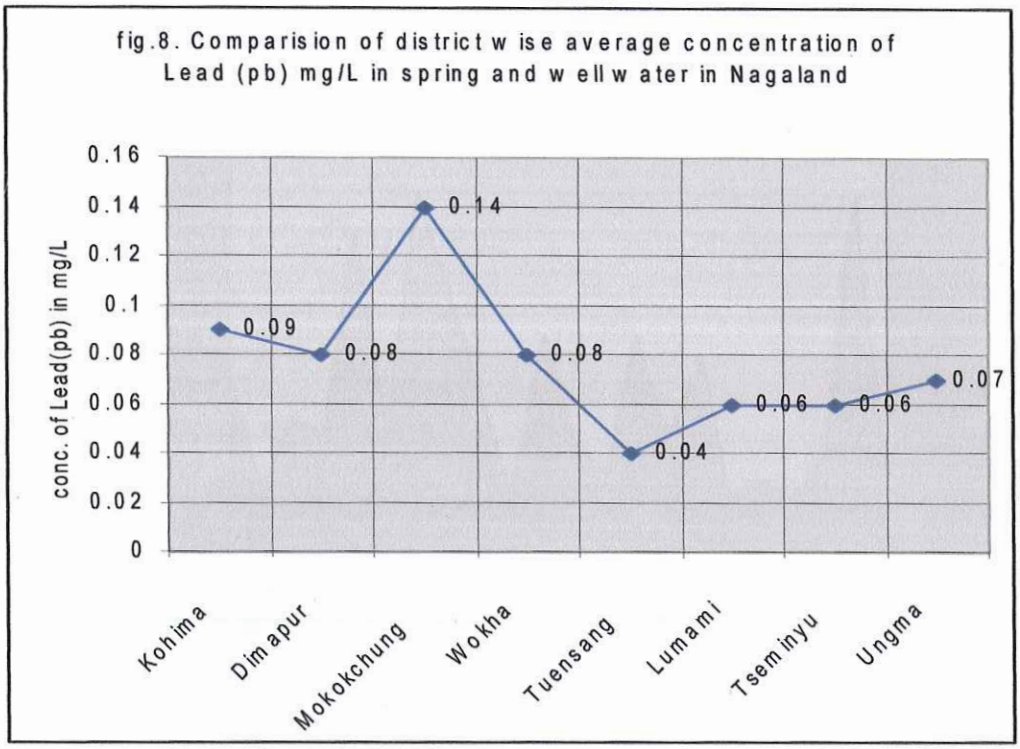


fig.8. Comparision of district w ise average concentration of Lead (pb) mg/L in spring and w ell w ater in Nagaland
conc. of Lead(pb) in mg/L
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.09
0.08
0.14
0.08
0.04
0.06
0.06
0.07
Kohima
Dimapur
Mokokchung
Wokha
Tuensang
Lumami
Tseminyu
Ungma

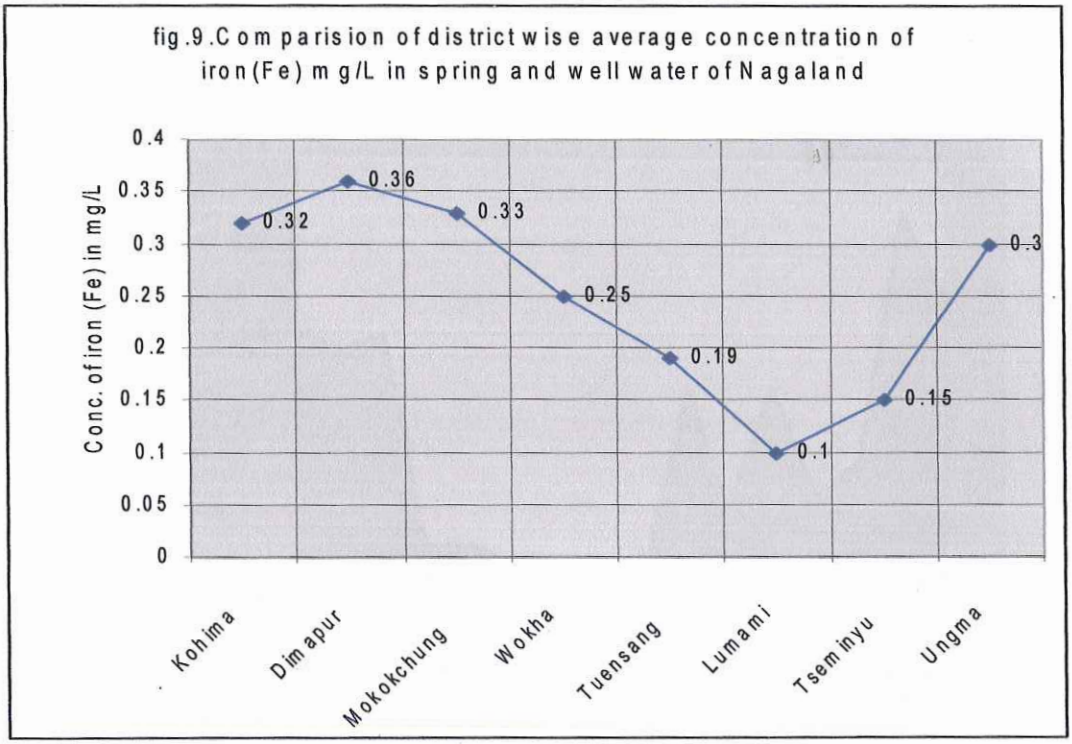


fig.9.Comparision of district wise average concentration of iron(Fe) mg/L in spring and well water of Nagaland
Conc. of iron (Fe) in mg/L
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.32
0.36
0.33
0.25
0.19
0.1
0.15
0.3
Kohima
Dimapur
Mokokchung
Wokha
Tuensang
Lumami
Tseminyu
Ungma

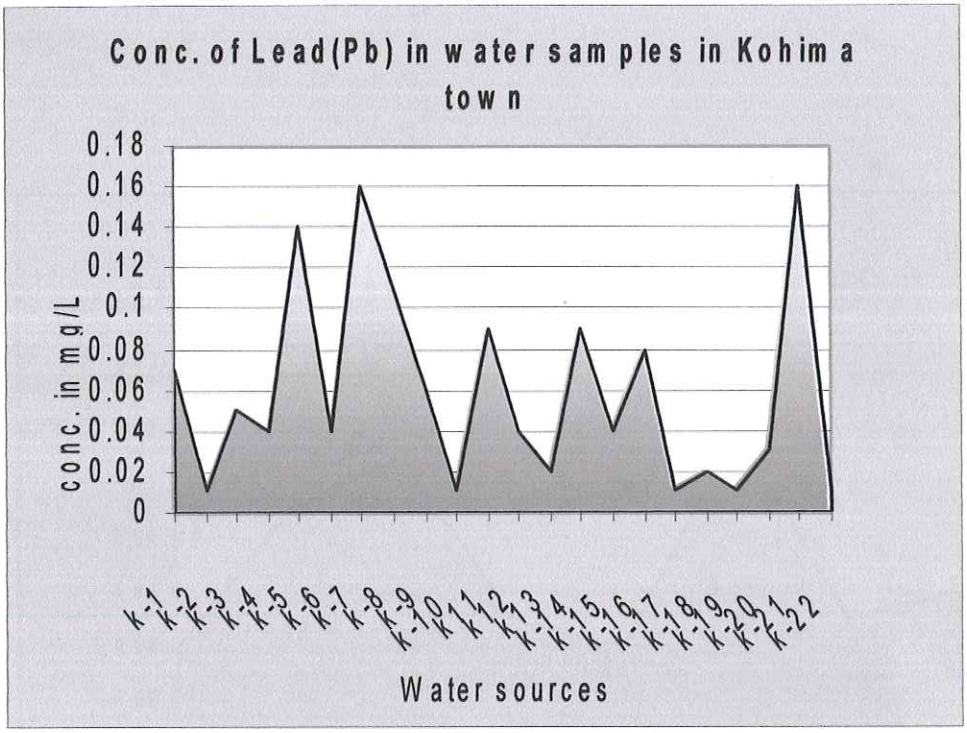


Fig.11. Concentration of lead (mg/L) in water samples in Kohima

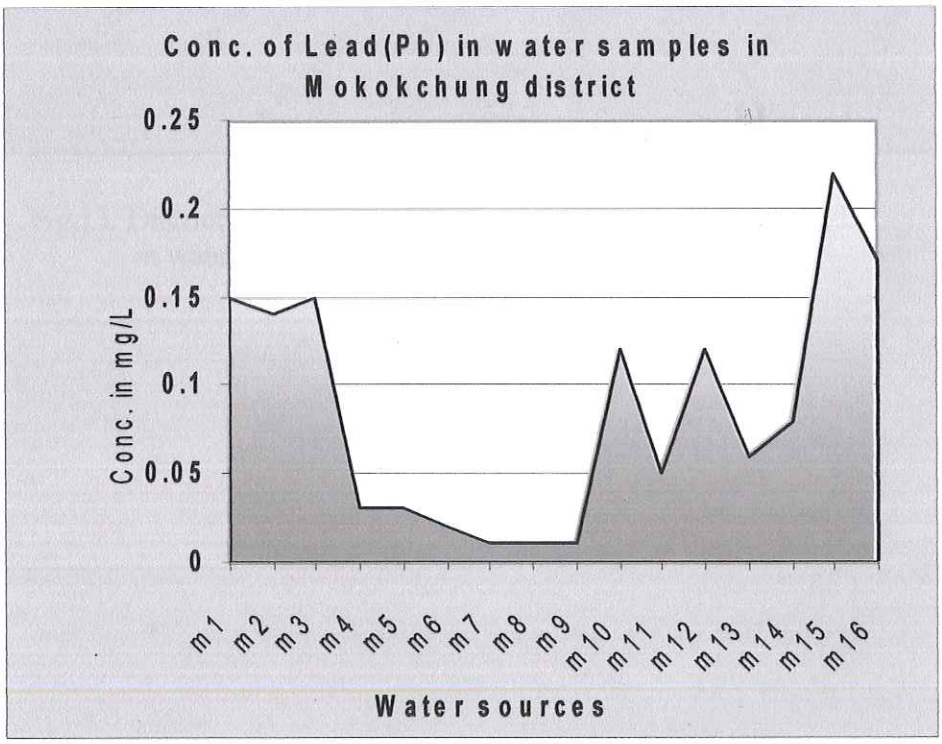


Fig.12. Concentration of lead (mg/L) in water samples in Mokokchung

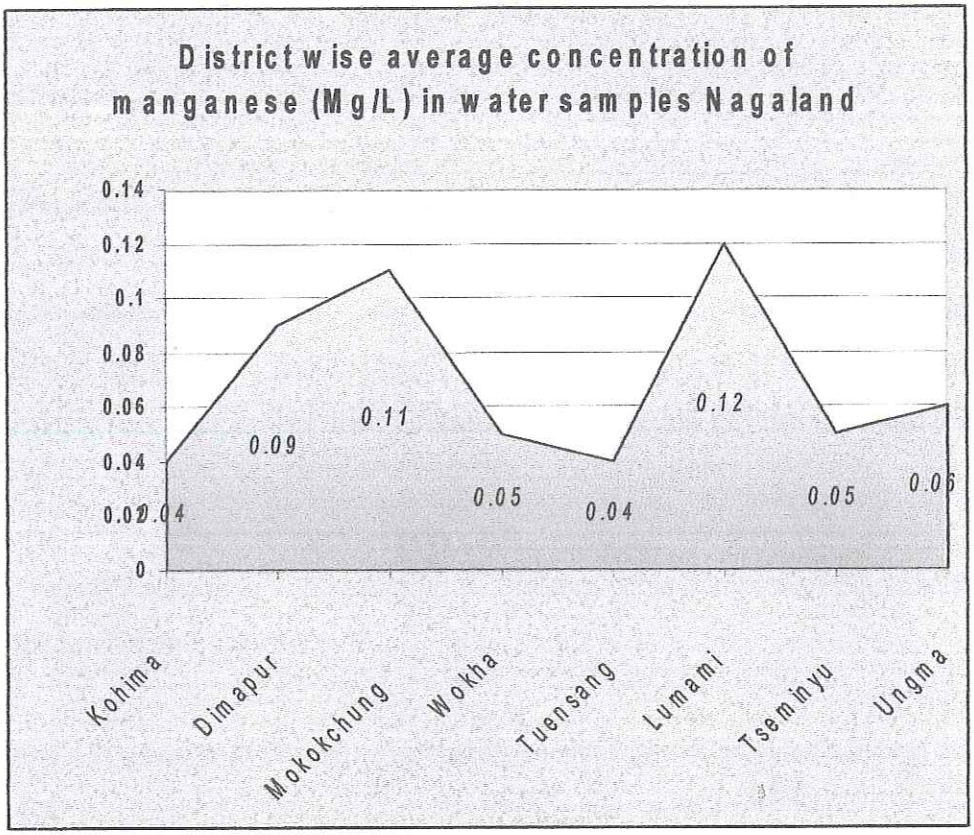


Fig.13. District wise average concentration of manganese (mg/L) in water samples Nagaland.

CHAPTER-6

RESULTS AND DISCUSSIONS

6.1 Introduction

In this study, an attempt has been made to characterize and assess the qualities of spring and well water (surface and ground water) available in and around the major towns and its adjoining areas in Nagaland. The results of the physiochemical characteristics and the trace elemental (heavy toxic metal) analysis of the water sample collected from different districts for four continuous years (2005-08) are summarized in Table.5.1.1.1 to 5.2.8.1.

The averages results of water quality of different water samples of Nagaland are also summarized in Table 5.3.1 to 5.3.7.

6.2 Results and discussions of the experimental observations of physiochemical parameters

6.2.1 Colour.

The colour of water samples was observed by visual method and it was found that the colour of almost all the water sample appeared colourless; however some ground water samples (Sample code.D-2, D-7, D-9, D-22 and D-23) of Dimapur were slightly turbid which may be due to the presence of effluent and sedimentation of clays and soil and similar particulate matter detectable by the naked eye. Nevertheless the colour of water samples was all acceptable.

6.2.2. Water temperature.

The ranges of Water temperature was found to be 13-22^{0}C in Kohima, 14.6-23^{0}C in Mokokchung,16.6-24^{0}Cin Dimapur,14.7-22^{0}C in Tuensang town,15.2-23^{0}C in Wokha,14.5-23^{0}C in Ungma Village under Mokokchung district, 15-23^{0}C in Tseminyu Sub- division under Kohima and 15.7-23^0 C in Lumami under Zunheboto district respectively. And as expected, the temperature of water samples collected in winter season (Jan-Mar) was lower by more than 5^0 C than the sample collected in summer (Jun-Sept)

The temperature of all the water samples collected from different districts were within the permissible limit of 40 ^{0}C as per IS 2490-1983.

6.2.3. pH.

It was observed that the pH of water samples collected from different places of Nagaland showed the pH ranges: 5.691-7.18 in Kohima, 6.65-7.42 in Mokokchung, 6.52-7.23 in Dimapur, 6.68-7.01 in Tuensang, 6.31-6.87 Wokha in, 6.36-7.56 in Ungma village, 6.02-6.83 in Tseminyu and 7.24-7.66 in Lumami respectively.

The pH of sample no.12, 14 &15 under Kohima and sample no.M-10, 12, 13 &15 under Mokokchung Town was found to be acidic in the ranges of 5.56-5.61 and 5.64-5.80 respectively. In addition the pH of sample no.U-4 under Ungma was found to be alkaline in the ranges of 7.89-8.34. Although, all the above values are closer to the maximum and minimum permissible limit, it is not highly alarming as the samples come within the tolerance limit [28]. Regarding the change in pH value for the last four consecutive years it was observed that the value marginally decreases with the passage of years which indicate the water slightly turning acidic as the pH value of water samples slightly decreases in the latter part of the studies. It was also observed that the pH value of most of the samples collected during summer (Monsoon) was higher (more alkaline) as compared to winter season.

6.2.4. Electrical Conductivity.

The results of the analyses of electrical conductivity of different districts in Nagaland was found to be 60-1380 μs cm^{-1} in Kohima , 120-912 μs cm^{-1} in Mokokchung, 241-1820 μs cm^{-1} in Dimapur, 548-632 μs cm^{-1} in Tuensang, 169-669 μs cm^{-1} in Wokha, 121-909 μs cm^{-1} in Ungma Village under Mokokchung district, 63-72 μs cm^{-1} in Tseminyu and 123-454 μs cm^{-1} in Lumami under Zunheboto district respectively.

The electrical conductivity (EC) of some ground water samples in Dimapur was found to be very high, in the ranges of 2023–2333 mg/L indicating the high minerals contents in water. Moreover, a comparison of electrical conductivity of different districts of Nagaland shows the highest electrical conductivity in Dimapur while Tseminyu areas have the lowest value of EC in ranges of 63-72 mg/L. Kohima and Mokokchung have moderate and above moderate values of electrical conductivity. In addition, the value of EC in water samples collected in summer indicate lesser concentration as compared to winter and can be concluded that the particles, ions in water are washed away during monsoon, thereby decreasing the concentration of EC. It was also observed that the electrical conductivity was marginally higher at the latter part of these four years consecutive studies.

6.2.5. Total dissolved substance (TDS)

The result of TDS was found to be 31-612 mg/l in Kohima, 60-461 mg/l in Mokokchung, 122-910 mg/l in Dimapur, 279-318 mg/l in Tuensang town, 44-347 mg/l in Wokha, 61-450 mg/l in Ungma Village under Mokokchung district, 31.3-39.6 mg/l in Tseminyu Sub- division under Kohima and 64-232 mg/l in Lumami under Zunheboto district. TDS and electrical conductivity are directly correlated and as the TDS increases the electrical conductivity also increases. Therefore, in all the samples the value of TDS was found to be in proportion with electrical conductivity. The TDS value, like EC in

some selected sample in Dimapur district was found to be above permissible limit in the range of 1011-1166 mg/l. Besides, A comparisons of TDS of different districts of Nagaland shows the highest TDS contents in Dimapur while Tseminyu areas has the lowest value of TDS in ranges of 31.3-39.6 mg/l. The high concentration of TDS was mainly observed in ground water sample in Dimapur as well as a few samples in Kohima. Kohima, Mokokchung and Tuensang have moderate and above moderate values of electrical conductivity. Moreover, the value of TDS in water samples collected in summer indicate lesser concentration as compare to winter and can be concluded that the particles, ions in water are washed away during monsoon ,thereby decreasing the concentration of TDS. It was also observed that the electrical conductivity was marginally higher during the latter part of these four years consecutive studies.

6.2.6 Dissolved Oxygen (DO)

The analysis of dissolved oxygen of surface and ground water of different districts in Nagaland was found to be in the ranges 10-23 mg/L in Kohima, 9.5-22 mg/L in Mokokchung, 7.9-19 mg/L in Dimapur, 11-25 mg/L in Tuensang, 8.9-24 mg/L in Wokha, 8.2-24 mg/L in Ungma, 8.3-23 mg/L in Tseminyu and 10-24 mg/L in Lumami respectively.

It was observed that few samples: sample no.U-12, 13 and 14 in Ungma, K-2, k-4, k-30 & k-31 in Kohima, M-11 in Mokokchung , D-2, D-9, D15 & D-16 and R-5 in Tseminyu have lower DO contents. Despite lower contents of DO in some selected water samples, all the selected samples in Nagaland adhered to the guidelines of permissible limit. Regarding the comparison of DO content in summer and winter, it was observed that most of the samples in summer have lower DO contents than the samples in winter. The reduction of DO content in water bodies especially during summer (monsoon) may be due to the presence of high oxygen demanding effluent and increase in organic load that entered into the water system during rainfall.

6.2.7 Biological Oxygen Demand (BOD).

The BOD of surface and ground water of different places of Nagaland were in the range 1.9-3.3 mg/L in Kohima, 2.2-3.1 mg/L in Mokokchung, 1.4-2.8 mg/L in Dimapur, 1.9-3.2 mg/L in Tuensang, 2.5-3.4 mg/L in Wokha, 2.7-3.2 mg/L in Ungma, 2.5-3.3 mg/L in Tseminyu and 2.5-3.2 mg/L in Lumami respectively.

It was observed that, few samples: sample no.U-12,13 and 14 in Ungma, K-2,k-4,k-30 & k-31 in Kohima, M-11 in Mokokchung , D-2,D-9,D15 & D-16 and R-5 in Tseminyu have higher BOD contents. Despite higher contents of BOD in some selected water samples, almost all the selected samples in Nagaland adhered to the guidelines of permissible limit. Regarding the BOD content in summer and winter, it was observed that most of the samples in summer have higher BOD contents than the samples in winter. The increased value of BOD contents in water bodies especially during summer (monsoon) may be due to the presence of high oxygen demanding effluent and increase in organic load that entered into the water system during rainfall which indicates the BOD value. However, the BOD value of most of the water samples of Kohima, Tuensang, Lumami, Ungma, Tseminyu were well within the permissible limits.

6.2.8. Chemical Oxygen Demand (COD).

The Chemical Oxygen Demand of surface and ground water of different places of Nagaland were in the range 78-87 mg/L in Kohima, 82-90 mg/L in Mokokchung, 89-98mg/L in Dimapur, 78-84 mg/L in Tuensang, 76-85 mg/L in Wokha, 73-83mg/L in Ungma, 71-84mg/L in Tseminyu and 73-83 mg/L in Lumami respectively. Regarding the COD contents in the samples collected in summer and winter season, it was observed that water samples in summer show marginally higher percentage of COD than the samples in

winter. The result may be due to the presence of more organic compounds that may come and enter water bodies during monsoon. Nevertheless, the COD value of all the water samples in Nagaland was found to be within the tolerance limit of BIS standard of 250mg/L.

6.2.9. Total Hardness

The result of the total hardness of surface and ground water (spring and well water) of different places in Nagaland were in the range 32.4-44.3 mg/L in Kohima, 44.5-65.3 mg/L in Mokokchung, 43.4-120.3 mg/L in Dimapur, 34.6-43.1 mg/L in Tuensang, 46.1-68.3 mg/L in Wokha, 34.2-69.5 mg/L in Ungma, 32.4-48.9 mg/L in Tseminyu and 34.6-76.3 mg/L in Lumami respectively.

According to the degree of hardness, the waters are commonly classified as follows[30].

Classification of Hardness

Quality	*Hardness as $CaCO_3$ in (mg/L)*
Soft	*0-75*
Moderate	*75-150*
Hard	*150-300*
Very hard	*Above 300*

Based on the above table, the total hardness of water in Kohima, Mokokchung, Tuensang, Wokha, Ungma, Tseminyu and Lumami are found to be soft in the ranges of 32-68mg/L approximately. However most of the water samples collected from Dimapur shows hardness value from moderate to hard. It was also observed that surface waters are softer than ground water as was evident from the samples collected from Dimapur area where the samples was all (tube well) ground water. As regard to the samples collected in

summer and winter season, it was observed that the hardness values in water samples collected in winter was higher than the sample collected during summer.

6.2.10. Calcium

The concentration of calcium in spring and well water of different places of Nagaland was analyzed by EDTA titrometric method as well as atomic absorption spectroscopy. The average concentration were in the range 25 mg/L in Kohima, 29 mg/L in Mokokchung, 58 mg/L in Dimapur, 23 mg/L in Tuensang, 27 mg/L in Wokha, 34 mg/L in Ungma, 26 mg/L in Tseminyu and 46 mg/L in Lumami respectively. The permissible limit of calcium in potable water is 75-100 mg/L.

In general, the representative water samples collected from different districts of Nagaland was found to have calcium well within the tolerance limit. However, on comparison of samples collected from different district of Nagaland, the water samples from Dimapur shows higher concentration of calcium. Also when comparing the calcium concentration in surface and ground water, it was found that ground water showed higher concentration than the surface water. This may be due to the accumulation of organic and inorganic solid in the ground water sample as all ground water showed high contents of TDS.

6.2.11. Magnesium

The concentration of Magnesium in surface and ground water (spring and well water) of different places of Nagaland was done by EDTA titrimetric method as well as atomic absorption spectrophotometer. The average concentration were in the range 18 mg/L in Kohima, 17 mg/L in Mokokchung, 35 mg/L in Dimapur, 18 mg/L in Tuensang, 30 mg/L in Wokha, 20 mg/L in Ungma, 21 mg/L in Tseminyu and 25 mg/L in Lumami respectively. Thus in general, the presence of magnesium in almost all the water samples

under study was found to be within the tolerance limit of 50-75 mg/L. With regard to the samples collected from different district of Nagaland it was found that concentration of magnesium in samples from Dimapur and Wokha districts shows a higher concentration as compared to other districts. In Wokha it was found that the concentration of magnesium was higher than the calcium though in all the districts calcium concentration was more than the magnesium. Again, when comparing the magnesium contained in spring and well water, it was found that the sample collected from ground water showed higher concentration than the sample from surface water. This may be due to the accumulation of organic and inorganic solid in the ground water sample as all ground water showed high content of TDS.

6.3. Result and discussions of experimental observation of Trace elements

The result of the trace heavy metals analysis of representative water samples collected from different parts of Nagaland viz. Kohima, Dimapur, Mokokchung, Wokha, Tuensang, Ungma village, Tseminyu town and Lumami indicate Ag, As, Ca, Cd, Zn, Ni and Mg concentration are all within the permissible limit and adhere to the WHO guidelines for domestic water . However, Result of the analysis of water samples indicates some samples from Mokokchung and Kohima have lead (Pb) concentration high above the tolerance limit. Also Copper (Cu) and manganese (Mn) concentration above the permissible limit was detected in samples from Mokokchung and Kohima. The concentration of iron (Fe) much above the maximum permissible limit was detected in many samples of Dimapur district of Nagaland.

6.3.1 Lead

The result of concentration of Lead in surface and ground water (spring and well water) samples collected from various part of Nagaland indicate in the range 0.02-0.14 mg/L in Kohima, 0.05-0.14 mg/L in Dimapur, 0.03-0.28 mg/L in Mokokchung, 0.03-0.14 mg/L in Wokha, 0.01-0.04 mg/L in Tuensang, 0.03-0.10 mg/L in Lumami, 0.03-0.09 mg/L in Ungma and0.05-0.09 mg/L in Tseminyu respectively.

Regarding the district wise average concentration of lead in the samples, it was found to be in the range 0.08 mg/L in Kohima, 0.11 mg/L in Mokokchung, 0.08 mg/L in Dimapur, 0.04 mg/L in Tuensang town, 0.08 mg/L in Wokha, 0.07 mg/L in Ungma Village under Mokokchung district, 0.06 mg/L in Tseminyu Sub- division under Kohima

and 0.06 mg/L in Lumami under Zunheboto district indicating the concentration of lead in most of the samples above the maximum permissible limit (Table 5.3.2).

The following samples: m-1, m-2, m-3, m-10, m-12, m-15, m-16 under Mokokchung, k-5, k-7, k-8, k-11 under Kohima, w-1, w-2 under Wokha showed alarming increase in the concentration of lead which is a much higher value than the maximum permissible limit of 0.1 mg/L.

6.3.2 Cadmium

The analysis of cadmium in spring and well water indicate the average concentration of cadmium in the range 0.001 mg/L in Kohima, 0.001 mg/L in Mokokchung, 0.002 mg/L in Dimapur, 0.001 mg/L in Tuensang, 0.001 mg/L in Wokha, 0.001 mg/L in Ungma Village under Mokokchung district, 0.001 mg/L in Tseminyu Sub-division under Kohima and 0.001 mg/L in Lumami under Zunheboto district and that all the ranges adhere to the guideline for domestic water of 0.03mg/L.[28]

Comparing the district wise concentration of cadmium, it was found that the samples collected from Kohima, Mokokchung and Dimapur shows higher concentration in the range 0.001-0.002 mg/L as compared to the samples from other districts in the range 0.00-0.001 mg/L. indicating higher rate of pollution. Besides, it was also observed that water bodies in and around solid waste deposits have higher concentration of cadmium. For example sample No. k-7 (Table- 5.2.3.1). Nevertheless all the concentration was in the range within the WHO guidelines value of 0.03 mg/L[28].

6.3.3 Arsenic

The result of the analyses of arsenic in spring and well water collected from different district of Nagaland was found to be in the average range of 0.001 mg/L for all the samples (Table-5.3.2). All the representative samples showed concentration of arsenic well below the maximum tolerance limit of WHO guidelines 0.01mg/L. [28]

In fact, it is reported that water samples from the Tuli areas under Mokokchung district and some parts of Mon district in Nagaland have arsenic consideration above the tolerance limit [24, 25]. However, this study does not cover the reported areas where arsenic consideration in drinking water is above the permissible limit.

6.3.4 Silver

Regarding the concentration of silver in spring and well water it was observed that many water samples have low concentration of silver and the presence of silver could not be detected in many samples especially from Wokha, Tseminyu and Ungma areas. The average concentration of silver in surface and ground water collected from various district of Nagaland was found to be in the range of 0.00- 0.001 mg/L (Table-5.3.2). All the values were below the maximum permissible limit of 0.05 mg/L

6.3.5 Iron

The analysis of iron showed the average concentration in surface and ground water in the range 0.05-0.58 mg/L in Kohima, 0.03-0.34 mg/L in Mokokchung, 0.05-0.68 mg/L in Dimapur, 0.05 mg/L in Tuensang, 0.05-0.26 mg/L in Wokha, 0.03-0.39 mg/L in Ungma Village under Mokokchung district, 0.05-0.09 mg/L in Tseminyu Sub- division under Kohima and 0.02-0.18 mg/L in Lumami under Zunheboto district (table no. 5.3.4). It was also observed that many samples under Dimapur shows higher concentration of iron and above the permissible limit for drinking water guidelines of 0.3 mg/L (BIS.10500-1983; WHO (2004). However, sample from other districts of Nagaland have iron concentration well within the permissible limits.

Regarding the concentration of iron in different types of samples it was observed that the concentration of iron was higher in ground water than in the surface water as many ground water samples collected from Dimapur showed higher concentration of iron.

6.3.6 Copper

The result of copper analysis indicates the average concentration of copper in surface and ground water in the range 0.16 mg/L in Kohima, 0.13 mg/L in Mokokchung, 0.06 mg/L in Dimapur, 0.05 mg/L in Tuensang, 0.05 mg/L in Wokha, 0.06 mg/L in Ungma Village under Mokokchung district, 0.07 mg/L in Tseminyu Sub- division under Kohima and 0.06 mg/L in Lumami under Zunheboto district. Regarding the comparison of copper concentration in samples collected from different district, it was observed that Kohima and Mokokchung have higher copper concentration than the samples from other districts of Nagaland. However the concentration of copper in surface and ground water of Nagaland were found to be within the tolerance limit of 0.05 mg/L (BIS, 10500-1983).

6.3.7 Zinc

The analyses of zinc in spring and well water of Nagaland indicates the range 0.06-0.88 mg/L in Kohima, 0.12-3.88 mg/L in Dimapur.0.27-3.39 mg/L in Mokokchung, 0.27-2.39 mg/L in Wokha, 0.07-1.89 mg/L in Tuensang, 0.45-0.78 mg/L in Lumami, Zunheboto, and 0.13-0.99 mg/L in Ungma 0.06-1.99 mg/L in Tseminyu respectively (table no.5.3.4) and the average concentration of zinc is 0.20 mg/L in Kohima, 1.01mg/L in Mokokchung, 3.13 mg/L in Dimapur, 0.07 mg/L in Tuensang town, 0.12 mg/L in Wokha, 0.40 mg/L in Ungma Village under Mokokchung district, 0.17 mg/L in Tseminyu Sub- division under Kohima and 0.615 mg/L in Lumami under Zunheboto district (Table 5.3.2).

It was observed that water samples from Kohima, Wokha, and Tseminyu have lesser concentration of copper as compared to the samples collected from other parts of the state. Nevertheless, the concentration of zinc in all the surface and ground water collected from various parts of Nagaland adhered to the WHO guidelines value for drinking water maximum permissible limit of 5.00 mg/L .[28]

6.3.8 Nickel

The analyses of nickel in spring and well water samples collected from the various part of Nagaland indicates the concentration in the range 0.001-0.002 mg/L which shows that the water under studies so far is free from nickel pollution (table no.5.3.2).

6.3.9 Manganese

The result of the analysis of manganese in surface and ground water was found to be in the ranges 0.00-0.13 mg/L in Kohima, 0 .03-0.16 mg/L in Dimapur, 0.02-0.17 mg/L in Mokokchung, 0.02-0.27 mg/L in Wokha, 0.02-0.13 mg/L in Tuensang, 0.04-0.21 mg/L in Lumami 0.04-0.18 mg/L in Ungma and 0.02-0.07 mg/L in Tseminyu respectively. The average concentration is 0.07 mg/L in Kohima, 0.13 mg/L in Mokokchung, 0.12 mg/L in Dimapur, 0.09 mg/L in Tuensang town, 0.07 mg/L in Wokha, 0.11 mg/L in Ungma Village under Mokokchung district, 0.05 mg/L in Tseminyu Sub-division under Kohima and 0.14 mg/L in Lumami under Zunheboto district respectively (table no.5.3.4). The concentration of manganese in sample no.K-2, 3, 4, 7, 19 & 20 under Kohima ,sample no.M-8, 9, 11, 12, 13, 14, 15 & 16 under Mokokchung and L-4 & 5 under Lumami was found to be above BIS and WHO guidelines values of 0.1 mg/L [35]. The maximum permissible limit of manganese for potable water is 0.1 mg/L (BIS 10500-1983).However, the concentration of manganese in rest of the surface and ground water samples collected from various parts of Nagaland were found to be within the maximum permissible limit.

CHAPTER-6

CONCLUDING DISCUSSION

6.1 Conclusion

Based on the analysis of different physiochemical parameters and trace heavy metal elements in spring and well water (surface and ground water) it was observed that the physiochemical characteristics of drinking water sources is found deteriorating slowly with the passage of years and need immediate attention in order to restore the water quality in the State.

It was also observed that many water sources shows lower pH value in the latter part of the studies. The value of Electrical conductivities and total dissolved solid shows an increase with the passage of years which indicates that the water bodies are slowly becoming polluted as all these values largely depend on solid waste, anthropogenic waste. Regarding the comparison of pH, electrical conductivities and total dissolved substance of different samples in different seasons, it was concluded that the value of pH marginally increases during summer than in winter and this may be due to the fact that during summer the rain water washes away many chemicals especially detergents, pesticides, insecticides, fertilizers containing more alkaline salts etc from surface land and these enter into the unprotected water bodies thereby turning water into slightly basic. The increase in pH during summer reduces potability of water [67].

The analysis of dissolved Oxygen, biological oxygen demand and chemical oxygen demand of various water samples however indicates less or negligible pollution as most of the samples adhered to the standard guidelines values. As regards to comparison of the samples collected in different seasons, it was concluded that the value of dissolved oxygen marginally decreases in summer than in winter and the values of

biological oxygen demand and chemical oxygen demand increases during summer season than in winter. The reasons for this may be that during summer the monsoon brings all the organic and inorganic load into the water bodies thereby increasing the number of oxygen demanding microorganisms leading to the reduction of oxygen content thereby decreasing the dissolved oxygen and increasing the values of biological and chemical oxygen demand.

Regarding the comparisons of yearly samples of four consecutive years, it was observed that the water bodies become slightly polluted in the latter parts although the values fluctuate in many samples and no constant correlation was obtained. However majority of the samples indicates higher rate of pollution in the latter parts of the studies.

Concerning the values of different parameters in different districts of Nagaland, it was concluded that water samples from Kohima shows more acidity, and have lower pH value than the samples from other districts. The samples from Mokokchung have higher pH values and are hence more alkaline. The value of dissolved oxygen was almost all the same in all the representative samples in Nagaland. However the values of biological oxygen demand in water samples of Kohima, Mokokchung, Wokha and Tseminyu was higher, leading to the conclusion that the presence of organic matter was higher in the samples. The chemical oxygen demand on the other hand have higher value in the samples collected from Dimapur compare to the samples from other districts of Nagaland, indicating higher degree of pollution.

Analysis of water samples further revealed a higher value of Calcium and Magnesium especially in Dimapur district. The increase in concentration of Calcium and Magnesium is one of the reasons for the cause of hardness of water [75, 76]. However in other districts of Nagaland, the total hardness of water was all within the permissible limits.

The trace (heavy metal) elemental analyses of spring and well water shows some metals concentration above the maximum permissible limits. The concentration of Pb (lead) and Iron (Fe) in some areas of Kohima, Dimapur, Wokha, Mokokchung, Ungma and its adjoining areas showed far above the permissible limit prescribed by WHO and Indian Standard.

The concentration of lead in some parts of Mokokchung and its adjoining areas was found to be in the ranges of 0.15-0.22 mg/L (Permissible limit is 0.05-0.10 mg/l as per Indian Standard). Similar concentration of lead was also observed in some parts of Wokha, Kohima and Dimapur.

This high concentration of lead in water confirms that many surface and ground water sources are unprotected from domestic sewage and industrial effluents as most of the heavy metals and in particular the lead metal is generated from street dust.

It was also observed that many water sources of different districts in Nagaland have high concentration of iron above the permissible limits (Permissible limit is 0.3 mg/L). The concentration of Iron was found to be in the ranges of 0.45-0.67 mg/L in some parts of Mokokchung and its adjoining areas. And also some parts of Kohima in the ranges of 0.05-0.58 mg/L. In Dimapur the concentration of iron was in the range 0.06- 0.68 mg/L.

Studies of water samples also revealed the concentration of manganese in many sources above the permissible limit conforming that many solid substances are dissolved by the presence of bacteria.

6.2 Suggestions

The physiochemical characteristics of water in Nagaland shows a marginal increase in pollution level with the passage of years, although it does not reveal a high alarming rate. However, trace elemental analysis shows toxic elements such as lead, cadmium, iron and manganese present in many samples above the permissible standard limits. The concentration of lead above the permissible limit affect the central nervous system as lead is potentially hazardous and toxic to most forms of life [47]; the presence of cadmium causes adverse renal arterial change in kidney and the high concentration of iron makes the water objectionable and imparts an inky flavor to the water. The presence of Manganese imparts objectionable and tenacious stains to laundry plumbing fixtures, although it is not a potent toxic element.

It is therefore suggested that the government machineries, the local bodies as well as the individuals concerned give the utmost importance to protect and preserve the water sources. The public should be made thoroughly aware of the dangers of pollution and academia, NGOs, and local communities should be involved in the extension of such efforts.

The authority and local bodies must ensure the protection of catchments areas of all surface water as well as the dug well by making proper constructions, complete ban on disposal of domestic waste & garbage near the sources, discouraging the use of detergent in and around the sources, discouraging the use of chemicals and fertilizers, maintaining proper drainage, setting up water treatment plants and strict legislation and regulation to preserve and protect water sources. There should also be facilities to educate and train personnel in water management skills. If possible, the government agencies should create a water testing laboratory in all the districts and set up a laboratory inspection mechanism for ensuring that the quality of water adheres to the prescribed guidelines. Water security should be achieved by harvesting rain water and facilities to recycle municipal waste water created by setting up water treatment plants.

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