STUDIES ON POLLUTION STATUS OF BONDAMUNDA AREA OF ROURKELA INDUSTRIAL COMPLEX

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STUDIES ON POLLUTION STATUS OF BONDAMUNDA AREA OF ROURKELA INDUSTRIAL COMPLEX

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CHAPTER-I INTRODUCTION

1.1.1 ENVIRONMENT

"ENVIRONMENT" is the surrounding which constitutes all the conditions where organisms lives and thus consists of air, water, soil, food and sunlight which are the basic needs of all living beings and the plant life to carry on their functions. In short, we can say that the environment consists of both biotic and abiotic substances which create favorable conditions for the existence and development of living organisms. Environment can be defined in a number of ways such as

1. "Environment is the sum of all social, economical, biological, physical or chemical factors which constitute the surroundings of man, who is both creater and moulder of his environment".
2. "Environment refers to the sum total of conditions which surround man at a given point in space and time".
3. "Environment is the representative of physical components of the earth wherein man is the important factor influencing his environment".
4. "Environment is a holistic view of the world as it functions at any time, with a multitude of special elemental and socio-economic systems distinguished by quality and attributes of space and mode of behaviour of biotic and abiotic forms".

Whatever may be the definition but the facts remain same and consist of the following components.

1.1.2 COMPONENTS OF ENVIRONMENT

Environment consists of three important components, they are

a) Abiotic or Non-living Component

b) Biotic or living Component

c) Energy Component

The abiotic components are again subdivided into three categories

a) Lithosphere or Solid Earth

b) Hydrosphere or Water Component

c) Atmosphere or Gaseous Envelope

The abiotic or non-living component includes medium (soil, water, air and bodies of other organisms in case of parasites) and climate (temperature, light, wind, rainfall, snow, humidity etc.)

The biotic component of environment consists of flora and fauna including man as the important factor. Abiotic and biotic components constitute together the Biome environment. The energy component includes the solar energy, geochemical energy, thermal energy, electrical energy, hydroelectrical energy, nuclear, atomic energy and all other form of energy which plays an important role to maintain the real life of organisms. In all the components of environment a number of complex, self generating cycles are going on. Moreover there exists equilibrium among all the components of environment which makes the balances in nature. But due to some human activities the equilibrium in nature are disturbed which causes the environmental pollution.

1.1.3 FACTORS AFFECTING ENVIRONMENT

The four important ecological factors which are affecting the environment are as follows

1. Topographic or Physiographic Factors, which consists of altitude, direction of mountain chains, plateaus, plains, lakes, rivers, sea level and valleys etc.

2. Climate Factors or Aerial Factors, which include atmosphere, light, temperature and humidity etc.
3. Edaphic Factors, which comprise lithosphere or soil.
4. Biotic Factors, which include all types of interactions between different forms of life, for example men, animals, plants, and micro-organisms etc.

Life of organisms is affected by the combination of all these ecological factors, which are inter- related with each other. Thus the ecological factors under natural conditions operate in conjunctions and not individually.

1.1.4 TYPES OF ENVIRONMENT

The environment can be divided into two categories, they are

a) Natural Environment
b) Man-made or Anthropogenic Environment

Natural Environment

Natural environment operates through self regulating mechanism i.e. any change in natural ecosystem brought about by natural process is counter balanced by changes in the other component of the environment. This mechanism is known as homeostatic environment. Thus there exists a reciprocal relationship among various components of the environment. These components are water, air, noise, soil, forest, wild life, flora and fauna etc.

Man Made Environment

Man is the most important environmental agent, super headed by modern technologies capable of modifying the environment according to his needs. Man made environment includes technology transportation, housing etc. So, it is concluded that environment consists of an amalgamation of different systems like physical, chemical, biological, social and cultural elements and any change in the environment caused due to natural process or man-made process can effect the living organism adversely or beneficially.

1.1.5 DESCRIPTION OF ENVIRONMENT

The environment consists of four segments. These are:

a) Atmosphere: The atmosphere is the protective blanket of gases surrounding the earth, which sustains life on earth and saves it from the hostile environment of outer space. It is able to absorb most of the cosmic rays from outer space and a major portion of the electromagnetic radiation from the sun. It is able to transmit only near ultraviolet, visible, near infrared radiation and radio waves while filtering out tissue-damaging ultraviolet radiation below about 300 nm.

The atmosphere is subdivided into different regions of varying with altitudes. The most simple division is that of the lower atmosphere extending upto approximately 50 kilometers above the earth’s surface and the upper atmosphere, extending out into space.

The atmosphere plays a key role in maintaining the heat balance of the earth, through absorption of infrared radiation emitted by the sun and re-emitted from the earth.

The major components of the atmosphere are nitrogen and oxygen while the miner components are argon, carbon dioxide and some trace gases.

The atmosphere has been the source of oxygen (essential for the life on earth) and carbon dioxide (essential for plant photosysthesis). It also supplies nitrogen which nitrogen-fixing bacteria and ammonia-manufacturing plants use to yield chemically bound nitrogen essential for life. Furthermore, it has been a vital carrier of water from coeans to land, as part of the hydrologic cycle.

Unfortunately, with progress of science and technology, man has been dumping waste materials in to the atmosphere, which are posing a problem for survival of mankind itself on earth.

b) Hydrosphere : It refers to water in its various forms. It includes all types of water resources such as oceans, seas, rivers, lakes, streams, reservoirs, glaciers, polar ice caps and ground water (i.e. water below the earth’s surface). About 97% of the earth’s water supply is in the oceans while the high salt content does not allow its use for any human consumption. About 2% of the water resource gets locked in the polar ice caps and glaciers, while only 1% is found as fresh water (surface water-river, lakes, streams and ground water) for human consumption and other uses.

The contamination of surface water takes place by pesticides and fertilizers in agricultural run-off water, human and animal wastes in sewage and industrial wastes. Water-borne diseases from sewage alone have killed millions of people in developing countries.

Aquatic environmental chemistry is a proper understanding of the sources, transport, characteristics and chemical species of water.

c) Lithosphere : This is the outer mantle of the solid earth, consisting of minerals occurring in the earth’s crust and the soil. The latter comprises a complex mixture of minerals, organic matter, air, and water. The soil is the most important part of the lithosphere.

d) Biosphere : This denotes the realm of living organisms and their interactions with the environment viz, atmosphere, hydrosphere and lithosphere. The biospheres as well as environment are influenced considerable by each other. Thus, the oxygen and carbon dioxide levels of the atmosphere are based entirely on the plant kingdom. Because of the fact, green plants alone have been more or less responsible for the accumulation of in the atmosphere, through photosynthesis and decay, the original atmosphere having been devoid of oxygen.

The biological world, in general, has been intimately related to energy flows in the environment and water chemistry. The biosphere is influenced tremendously by the chemistry of the environment and in term exerts a powerful influence upon the chemistry of most environments, especially the lithosphere and hydrosphere.

1.1.6 ENVIRONMENTAL POLLUTION

Environmental pollution is the most horrible ecological crisis to which we are subjected today. It is due to the rapid Urban-industrial technology revolution and speedy, exploitation of natural resources by man, population explosion. Today the environment has become foul, contaminated, undesirable, and therefore harmful for the health of living organisms, including man. The splendid plentifulness of nature is a heritage that should never be spoiled. But the unlimited rapacious exploitation of nature by man has disturbed the delicate ecological balance existing between living and non-living components on the planet earth. The root cause of environmental pollution has been the man's misbehavior with the nature under the false ego that he is the master of nature. This undesirable situation created by man has threatened the survival of man himself and other living biota on the earth.

The word 'pollution' derived from the latin word pollutionem (meaning to define or make dirty) is the act of polluting the environment. The term pollution is defined in various ways. For example

1. Pollution is the addition of the constituents to water, air, land, which adversely alter the natural quality of the environment.

2. Pollution is the unfavorable alternation of our environment, largely because of human activities.
3. Pollution means the addition of any foreign material like inorganic, organic, biological or radiological or any physical change occurring in nature which may harm or affect living organisms directly or indirectly, immediately or after a long time.
4. Pollution is the introduction of surplus energy or waste matter in to the environment by man’s activities which directly or indirectly causes hazard to main and his environment.

1.1.7 POLLUTANT

A pollutant has been defined according to the Environmental Protection Act (EPA[13]), 1986 as “a harmful solid, liquid or gaseous substance present in such concentration in the environment which tends to be injurious to environment”.

On the basics of their forms in which they exist in environment after their release, pollutants can be divided into the following categories:

1. Primary Pollutant (SO_x, NO_x, CO etc.)
2. Secondary pollutants i.e. substance derived from primary pollutants like Peroxy Acetyl Nitrate (PAN).
3. Biodegradable pollutants which substance can be decomposed removed or consumed and thus reduced to acceptable levels e.g. domestic wastes, heat etc.
4. Non-biodegradable pollutants: these either do not degrade or degrade only very slowly or partially and there by pollute environment.

Thus we can conclude that, when the waste products produced by human activity are not efficiently assimilated, decomposed or otherwise removed by natural, biological or physical process than they cause adverse affect and are termed pollutants.

1.1.8 TYPES OF POLLUTION

Pollution may be termed as natural pollution or artificial pollution.

Natural Pollution:- Natural pollution includes pollution of the environment caused due to natural process like forest fire, volcanic eruption, natural, organic and inorganic decay, earthquake etc.

Artificial Pollution:- It originates due to human activities which include industrialization, deforestation, urbanization etc.

Pollution can be classified according to the environment (air, water, soil, noise etc) in which it occurs or according to pollutants which cause the pollution.

Classification according to environment

1. Air Pollution
2. Water Pollution
3. Soil and Land Pollution

Classification according to pollutant

1. Thermal Pollution
2. Radioactive Pollution
3. Noise Pollution
4. Industrial Pollution
5. Chemical Pollution
6. Marine Pollution
7. Oil Pollution
8. Pesticide Pollution
9. Acid rain Pollution
10. Soap and Detergent Pollution etc.

1.2 SCOPE OF PRESENT STUDY

The present study was under taken at the Bondamunda Area of Rourkela Industrial Complex. Bondamunda is the municipality area of Rourkela. Rourkela is one of the most important industrial cities situated on Howrah-Mumbai Railway line in the State of Orissa and has population of more than four lakh. The population density in the industrial complex is 3,288 persons per square kilometer. The area is at 20 degree 12 min. North latitude and 84 degree 53 min. East longitude at the elevation of about 219 m. above mean sea level. The Industrial complex is situated approximately 215-230 m above the mean sea level. The cities spread over an area of 121.7 km^2 and close proximity of iron ore, dolomite, lime stone and coal belts. It is surrounded by Durgapur hill range. A perennial river Koel flows through this valley and meets another perennial river Sankh at a place known as Vedavyas on the outskirts of Rourkela. After this point of confluence at Vedavyas, the river is known as Brahmani, which is one of the 14 major river systems in the country. As can be seen from **Fig. 1.1**, the entire Industrial Complex is divided by a hill range and the hill is virtually a separation boundary between the localities of the steel township and the “Old Rourkela”. Steel Township contains various residential sectors and very well planned to protect the inhabitants from environmental pollution.

On the other side of the hill range lies Bondamunda area, Civil township, the Giant Steel Plant, several medium industries, like cement, refractories, sponge iron plant, explosive and chemicals and many more small scale industries. The construction of Rourkela Steel Plant was started with collaboration of the Federal Republic of Germany in October 1956. Its various units started production on different dates during 1958 and 1960 (Srinivasan[11] 1990). The major plant facilities and their capacities are given in **Table 1.1**. The raw materials like coal, hematite, limestone, dolomite etc. are available within a short radious of the plant. Besides these, bulk of raw materials comes from its own captive mines. The annual consumption of different raw materials is given in **Table 1.2**. The quantity of major products and by products produced by different units of Steel Plant is given in **Table 1.3**.

A survey from the regional transport office revealed that more than 1.5 lakh registered small and heavy vehicles are in the industrial complex.

1.3 OBJECTIVES

From the discussion of the scope of present study, i.e. motor vehicles, large population density and industries present in this area produce huge amount of pollutant which pollute the environment. The objective of the work is to study the environmental pollution (water, air and noise) of Bondamunda area. The important points are:

1. To evaluate the status of water quality based on the physico-chemical and metallic parameters of different sources of water.
2. To find the correlation coefficient among different water quality parameters
3. To calculate the Water Quality Index (WQI) of the analysed water samples.
4. To evaluate the status of ambient air quality based on the air quality parameters like SPM, SO_2 and NO_x.
5. To calculate the Air Quality Index (AQI) of the analysed air samples.
6. To evaluate the status of noise pollution level based on noise parameters.

1.4 AREA UNDER STUDY

The study was carried out by collecting water samples from fourteen localities. Out of fourteen localities, eight locations for tube well water (i.e. sector-B. Tilkanagar, Dumerta, Gundichapalli, R.S. colony, Bortoli and Diesel Colony), four localities for treated water (sector-A, Sector-C, Sector-E and Diesel Colony) and two localities for open well (i.e. Tilkanagar and

Dumerta) are selected (**Table 1.4**). For the investigation of status for air pollution, three sampling stations were selected, keeping in view, the important zones and nature of activities (i.e. Tilkanagar is residential cum industrial, Sector-C is residential cum traffic and Dumerta is residential) (**Table 1.5**). The position of these locations of water sampling stations and air sampling stations are shown in **Fig. 1.1** and **1.2** respectively. The survey of noise pollution was studied at various types of areas like residential areas, commercial areas, industrial areas, silence zone and traffic point. The different localities of these areas are given in **Table 1.6**.

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Table – 1.1 Major Plant Facilities and their Capacities Attached to Rourkela Steel Plant of SAIL

Sl No.	Facility	Number	Capacities
1.	Coke oven and By-product Plant	3 × 70 ovens + 2 × 80 ”	1.460.000 T/yr
2.	Sinter Plant	2 × 132 M^3	1.2 MT/yr
3.	Blast Furnace	3 × 1, 132 M^3 + 1 × 1, 653 M^3	1,600,000 T/yr
4.	Pig Casting Machine	2	1 × 100 T/day 1 × 1,600 T/day
	Steel Melting shop		
5.	a) L.D. Converter	3 x 50 + 2 x 60	1,550 T/yr
	b) O.H. Furnace	4 x 80	250,000 T/yr
6.	Rolling Mills		
	a) Bloonung and slabbong mill	1	1,800.000 T/yr
	b) Hot strip mill	1	1,106,000 T/yr
	c) Plate mill	1	200,000 T/yr
	d) Cold Rolling mill complex	1	748,000 T/yr
	e) Electrical sheet mill	1	50,000 T/yr
	f) ERW pipe plant	1	75,000 T/yr
	g) Spiral welded pipe plant	1	55,000 T/yr
	h) Silicon steel mill	1	CRNO 36,000 T/yr CRGO 37,500 T/yr
7.	Refractory Materials Plant	3	120 T/day
	a) Lime, shaft kiln	1	120 T/day
	b) Rotary kiln	1	120 T/day
8.	Captive Power Plant	5	25 MW each
		2	60 MW each
9.	Fertilizer Plant	1	460,000 T/yr CAN
10.	Slag Granulation Plant	1	0.6 MT/yr

Table – 1.2: Annual Raw Material Consumption by the Steel Plant, Rourkela

A. Raw Material	Years Consumption
(i) Coal	2.6 M.T (Coking)
(ii) Iron ore sinter	2.0 M.T (Lumps) 1.0 M.T (Fines) 1.2 M.T
(iii) Lime stone (Lumps and fines for BF and SP) SMS Grade	0.7 M.T (Lumps) 0.6 M.T (Fines) 0.5 M.T
(iv) Dolomite SMS Grade	0.12 M.T
(v) Manganese ore	0.3 M.T
(vi) Quartizite	About 60,000 T
(vii) Fluorspar	About 3600 T
(viii) Bauxite	About 3000 to 4000 T
(ix) Ferro Alloys	About 3000 to 4000 T of different ferro-alloys depending upon the types of steel produced.
B. Gases	
(i) a. L.P. Gas b. Coke oven Gas c. Mixed Gas	131.13 x 10^3 NM^3/hr 14.33 x 10^3 NM^3/hr 37.01 x 10^3 NM^3/hr
(ii) Coaltar Fuel	860 Tonnes / month

Table – 1.3 List of Major Products and by Products Produces by Steel Plant Per Month.

Sl No.	Name of products and by products	Quantity on metric tons per month (Avg. monthly figures of 1987-88)
1.	Ingot steel	92, 876 M.T
2.	Saleable steel	96, 352 M.T
3.	H.R. coils	58, 670 M.T
4.	Electric steel sheet	151 M.T
5.	C.R. sheet and coils	16, 717 M.T
6.	Galvanised sheet	12, 333 M.T
7.	Electric Tin plates	151 M.T
8.	ERW pipes	3, 003 M.T
9.	Spiral weld pipes	3, 595 M.T
10.	Cold Rolled sheet coils	1, 500 M.T
11.	Pig iron for sale	5, 385 M.T
12.	Granulated slag	14, 336 M.T
	Coal Chemical	Products
13.	Tar products	7, 738 M.T
14.	Carbolic oil products	80 M.T
15.	Ammonium sulphate	648 M.T
16.	Phenol Products	397 Kilo liters

Table – 1.4 Sample Number, Locations and Source of Water Sampling Stations

Sample No	Locations	Source
1	Sector-A	Treated
2	Sector-C	Treated
3	Sector-E	Treated
4	Sector-B	Tube well
5	Sector-D	Tube well
6	Tilkanagar	Tube well
7	Tilkanagar	Open well
8	Dumerta	Tube well
9	Dumerta	Open well
10	Gundichapalli	Tube well
11	R.S. Colony	Tube well
12	Bortoli	Tube well
13	Diesel Colony	Treated
14	Diesel Colony	Tube well

Table – 1.5 Descriptions of Air Sampling Stations

Sample No.	Name of sampling stations	Nature of Activities
S_1	Tilkanagar	Residential cum Industries
S_2	Sector-C	Residential cum Traffic
S_3	Dumerta	Residential

Table – 1.6 Measurements of Noise Levels at Various Types of Areas with Different Localities

Sl. No	Areas	Localities
1	Residential areas	1. Sector-A, 2. Sector-B 3. Sector-C, 4. Sector-D 5. Sector-E, 6. Diesel Colony 7. Tilkanagar 8. Dumerta 9. Gundichapalli 10. R.S. Colony
2	Commercial areas	1. General Post office 2. Railway Station 3. Bank 4. Local market
3	Industrial Area	1. Loco Shed 2. Marshalling Yard
4	Silence Zone	3. Hospital 4. College
5	Traffic Point	Sector-C

CHAPTER –II WATER POLLUTION

2.1.1 INTRODUCTION

Water is a vital natural resource, which is essential for multiplicity purposes. It is an essential constituent of all animal and vegetable matters. It is also an essential ingredient of animal and plant life. Its uses may include drinking and other domestic uses, industrial cooling, power generation, agriculture, transportation and waste disposal.

At the present state of national development, agricultural productivity in India, heavily dependent on rainfall and occurring, droughts in various parts of our country during the last decade, have given a series of jolts to the growth of our economy. Growing population, accelerating pace of industrialization and intensification of agriculture and also urbanization exert heavy pressure on our vast but limited water resources.

2.1.2 WATER POLLUTION

With the increase in the age of the earth, clean water is becoming more precious as water being polluted by several man made activities, e.g. rapid population growth, alarming speed of industrialization and deforestation, urbanizations, increasing living standards and wide spheres of other human activities. Ground water, surface water, rivers, sea, lakes, ponds etc are finding more and more difficult to escape from pollution.

The term water pollution refers to anything causing change in the diversity of aquatic life. The presence of too much of undesirable foreign substance in water is responsible for water pollution.

Water pollution is one of the most serious problems faced by man today. Since water is the vital concern for mankind and essential for man, animal and aquatic. It is the universal enabling chemical which is capable of dissolving or carrying in suspension of a variety of a toxic materials from mainly heavy flux of sewage, industrial effluents, domestic and agricultural waste. That is why it is of special interest to study the water pollution.

SOURCES OF WATER POLLUTION

Sources of contamination of water pollution are as follows.

i) Sewage and Domestic Wastes.
ii) Industrial Effluents
iii) Agricultural Discharges
iv) Pesticides and Fertilizers
v) Soap and Detergents
vi) Thermal Pollution etc.

i) Sewage and Domestic Wastes

About 75% of water pollution is caused by sewage and domestic wastes. If the domestic waste and sewage are not properly handled after they are produced and are directly discharged into water bodies, the water gets polluted. Domestic sewage contains decomposable organic matter which exerts on oxygen demand and sewage contains oxidisable and fermentable matter which causes depletion of D.O level in the water bodies,

ii) Industrial Effluents

Industrial effluents are discharged into water bodies containing Toxic Chemicals, Phenols, Aldehyaes, Ketones, Cyanides, Metallic Wastes, Plasticizers, Toxic Acids, Oil and Grease, Dyes, Suspended Solids, Radioactive Wastes etc. The principal types of industries which contribute to water pollution are Chemical and Pharmaceutical Industries, Steel Plants, Coal, Soap and Detergents, Paper and Pulp, Distilleries, Tanneries, Foods Processing Plants etc. These effluents when discharged through sewage system poison the biological purification mechanism of sewage treatment and pose several pollution problems.

iii) Agricultural Discharge

Plant Nutrients, Pesticides, Insecticides, Herbicides and Fertilizers Plants and Animal Debries are reported to cause heavy pollution to water sources. Now a day Fertilizers containing Phosphates and Nitrates are added to soil, some of these are washed off through rain fall, irrigation and drainage into water bodies thereby severely disturbing aquatic system. Organic wastes increase the BOD of the receiving water body. Some pesticides which are non-biodegradable, when sprayed remain in the soil for longer time and then carried in water bodies during rainfall.

iv) Soap and Detergents

Soap formed the Oleic Acid and Fatty Acid, when contact with water. Thus Acidity of water increases which disturb the aquatic life.

Detergents used as cleaning agents containing several pollutants which severely affect the water bodies. They contain surface activity agents and contribute to Phosphates of Sodium, Silicates, Sulphates and several other salt builders in water. Waste water contaminated with Detergents carries a huge cap of foam, which is anesthetic for all purposes. Since Detergents are composed of Complex Phosphates, they increase the concentration of Phosphates in water making it poisonous and causing Utrophication problems.

v) Thermal Pollution

The discharge of pollutants with unutilized heat from nuclear and thermal power adversely affects the aquatic environment. Apart from the electric power plant, various other industries with cooling system, contribute thermal loading of water bodies. These pollutants increase the Temperature of water and decrease the D.O value thus making condition unsuitable for aquatic life.

2.2 LITERATURE REVIEWS

Garg[19] *et al.* (1990) studied the various water quality parameters of ground water of Roorkee city. A systematic calculation of correction coefficient ‘r’ for eight water quality parameters of 72 samples collected from 6 different places of water supply sources (Tube Well) for 12 months and the result show that, large positive correlation between BOD and Permanent Hardness (r = 0.991) and for BOD and Total Hardness is r = 0.989. Rao[89] *et al.* (1991) studied the ground water of Musunur Mandal of Krishna district (A.P) and found that, the Physico-Chemical parameters like Nitrates, Fluorides, Phosphates, Iron and Sulphates were found to be within the permissible limits. Rao[90] *et al.* (1992) a studied the Physico-Chemical parameters of 23 bore wells and dug well of 23 villages of Challapalli Mandalam. The quality of well water was assessed by comparing with existing standards for important parameters, correlation coefficient ‘r’ among various water quality parameters were determined and found that, there is high incidence of Fluoride. Patel[72] *et al* 1994 studied the 21 Physico-Chemical parameters for the ground water samples from 14 rural areas of Rourkela Industrial Complex and found that all the rural areas are perfectly fit for drinking. Kumar[43] *et al* (1997) studied the pollution status of aquatic system of central part of Jharia coalfield with reference to heavy metal content in water like Cd, Pb, Fe, As and Se and found that the levels are higher then limits prescribed by BIS for drinking water due to run off from mining areas, overburden dumps, mine fires, domestic effluents, industrial effluents etc. are probably the sources of this heavy metal content. Panda and Singh[73] (1996) studied the major inorganic anions such as Nitrate, Sulphate, Fluoride, Chloride, and Phosphate in drinking water collected from 5 different source in Port City Paradeep and the results showed seasonal fluctuations. Mohapatra and Singh[55] (1998) studies for the determination of inorganic anions such as Nitrate, Sulphate, Chloride, Fluoride and Phosphates in drinking water collecting from 6 different sources in the City of Cuttack and the results of the inorganic anions obtained were well within the permissible limits recommended by WHO , ISI and ICMR. Naidu[60] *et al.* (1998) studied the water quality parameters in 3 north coastal town of Andhra Pradesh and the results indicate that, the water of Mindi Industrial Zone, Old Post Office and Jalaripet of Visakhapatnam, Kothapeta, Vakumpeta and Mayuri, theatre areas of Vizianagaram and Kothapeta and complex areas of Srikakulam towns are polluted either by industrials waste water or by sewage and saline waters. Kaplay[33] *et al.* (1998) studied the quality of Bore Well and Dug Well water around the industrial areas of Tuppa region of Nanded City, Maharashtra and the study reveal that, the ground water is contaminated due to industrial effluent and Total Hardness, Salinity, Calcium and Magnesium content as per Indian standards for drinking water. Crop production; and human and cattle lives are adversely affected by this pollution. Rambabu[86] *et al.* (1998) studied on the water quality parameters, like pH, Electrical Conductance, Total Hardness, Chloride, Sulphate, Nitrate and Fluoride and metals like Na, K, Ca and Mg of Chiral Town Open Wells, Prakasam District and found that out of 13 Open Wells 7 Open Wells are polluted in nature. Gonsalves and D’souza[21] (1998) studied the ground water samples in Coalngute, Goa and found that, the parameters like Nitrate, Phosphates, BOD and COD are high as per water quality standard. Koushik[31] *et al.* (1999) were collected water samples from three lentic water bodies (Motijlhil , Surajajkund and Ranital of Gwalior region and analysed for some heavy metal like Cu (0.017 to 0.09 mg/1), Zn (0.065 to 0.120 mg/1) Ni (below detection limit 0.001 mg/1 to 0.004 mg/1) Co (0.003 to 0.009 mg/1) Pb (0.002 to 0.009 mg/1) Mn (0.009 to 0.016 mg/1) Cr (0.020 to 0.048 mg/1) Cd (0.009 to 0.019 mg/l) and As (all the value are below the detection limit 0.001 mg/1). Seasonally lowest and highest value of all the parameters except Arsenic are recorded during summer and rainy season respectively in all the three water bodies and all the value of all the heavy metal parameters are found below the limit prescribed by different agencies. Balsankar and Nagrajan[4] (2000) collected ground water samples at different location in an around Cuddalore SIPCOT are analysed for their Physico-Chemical characteristics and found that, there is a wide variation in water quality from sample to sample and most of the water samples have high Total Dissolve Solids and unpleasand odour. Garg[20] *et al.* (2000) studied the Physico-Chemical parameters of 30 ground water samples in eastern part of Hisar city and found that, on an average all most all the samples had one or the other chemical constituent beyond WHO permissible limits. Someshekar[106] *et al.* (2000) collected 48 Tube Well water from Channapatona Town and surrounding and found that, quality of 80% of well is unsuitable for drinking in term of Hardness, 50% in terms of Magnesium and 20% in term of Nitrates and Calcium. Tyagi[113] *et al.* (2000) reported that, the concentration of some Physico-Chemical parameters of ground water like Colour, Hardness, COD, BOD, Fluoride, Chloride, Sulphate, Calcium, Nitrates, Phenols, Cyanide etc in the industrial areas of India was much higher than the permissible limits of WHO (1993) and ISI (1991) drinking water standards. Sohani[107] *et al.* (2001) collected 16 ground water samples from the Bore Wells of different colonies of Nandurbar Town (Maharashtra) and analysed for 15 parameters related to water quality and found that some Physico-Chemical parameters within the permissible limit and some are beyond the permissible limit of drinking water standards. High Iron content (0.0 to 5.80 mg/1) has been detected. Tiwari[109] *et al.* (2002) Studied the drinking water quality of residential colony, SAIL Satellite Township and four other sources of drinking water in Ranchi and found that higher values of Nitrate, Chloride, Calcium and Magnesium are obtained. Jeyras[27] *et al.* (2002) studied the Physico-Chemical parameters for water samples collected from 15 Bore Well situated in different streets of Bharati Nagar and found that, the water is Saline and Hard. Abdul[1] *et al.* (2002) studied the 20 Physico-Chemical parameters of 20 sampling stations and found that all the water bodies are contain high levels of Inorganic Salts and Total Hardness with high Electrical Conductance. Rani[88] *et al.* (2003) studied the drinking water quality of five rural places in and around Thittagudi, Tamilnadu and found most of the water samples have high TDS values and high Alkalinity. Padmavathy[70] *et al.* (2003) studied the water pollution of well waters taken from Ariyalur area in Tamilnadu and found that, the WQI values below 90. Mishra and Sahoo (2003) studied the ground water quality in and around Deogarh and found that, the Physico-Chemical parameters like pH, Conductance, TDS, TH, Na, K, Mg, Ca, Cl, SO_4 and HCO_3 indicate that, the ground waters are suitable both for domestic and irrigation use. Prakasam[80] (2004) studied the ground water quality of Kerala with special reference to Kollam District and found that, the ground water in Mayyanad Panchayat is slightly acidic (pH=5.4 to 7.7) which is unsafe for drinking where as in Kollam Corporation area is not problematic.

2.3 WORK DONE BY AUTHOR

The work on the present research work was started in March 1994 for a period of two years. Literature survey shows that, no systematic, extensive studies have been conducted on water pollution in Bondamunda area. Residents of this area use tube well, open well and treated water for consumption.

Monthly water samples have been collected in 2.5 litre capacity polythene bottles (soaked overnight in 2% nitric acid and washed well in distilled water) from each location and analysed for various Physico-Chemical and Metallic Parameters like Temperature, Turbidity, pH, Conductance, D.O, Total Hardness, Acidity, Alkalinity, Chloride, BOD, COD, Total Solids, Total Dissolved Solids, Sulphate, Nitrate, Calcium, Magnesium, Iron, Lead, Zinc, Manganese, Cadmium, Cyanide, Sulphide, Phenals, Oil and Grease and Hexavalent Chromium as per standard methods. (APHA[3] –1989, Goltermen[22] *et al.* – 1978, Monivaskam[48] – 1986, NEERI[63] – 1981, Perkin[83] – 1976, Taylor[108] – 1949, Traversy[111] – 1971, Trivedy and Goel[112] – 1986, Vogel[115] – 1964, Willard[116] – 1958)

2.4 METHODOLOGY

Temperature

The limnlogical characteristics of the water body depend upon solar radiations hence Temperature was recorded by a good thermometer with 0°C to 60°C range and having a least count of about 1°C. The Temperature of sample was measured at the time of sampling on the site.

Turbidity

Turbidity is an important parameter for characterizing water quality. It is an expression of optical property of a sample (water and wastewater) containing insoluble substance which causes light to be scattered rather than transmitted in straight lines.

The amount and angular distributions of this scattered light is governed not only by the quantity of the insoluble substances but also by their size, shape and refractive index. In most of the waters, Turbidity is due to colloidal and extremely fine depressions, suspended matters such as clay slit, finely divided organic and inorganic matter, plankton and other microscopic organisms also contribute to Turbidity. The Turbidity of a. sample is thus measured (Nephelo Turbidity Meter) from the amount of light scattered by the sample taking a reference with standard Turbidity suspension.

pH

pH is a term used universally to express the intensity of the acid or alkaline condition of a solution. It is a measure of Hydrogen Ion concentration or more precisely, the Hydrogen Ion activity. pH is defined as the "logarithm (base 10) of the reciprocal of the Hydrogen Ion concentration." It is an important factor in water chemistry. Since it enters into the calculation of Acidity and Alkalinity and processes such as coagulation, disinfection, softening and corrosion control. It is measured by a pH meter using a glass electrode which generates a potential varying linearly with the pH of solution in which it is measured.

Conductance

Electrical Conductivity is a measure of water’s capacity of conveys electric current. Electrical Conductivity of water is directly proportional to its dissolved mineral matter content. The unit of Conductivity is μmho/cm. Since Electrical Conductivity varies directly with the Temperature of the sample, the result is, usually reported at 25°C. Specific Conductivity of water sample was determined by Conductivity Meter calibrating the instrument by standard Potassium Chloride solution.

Dissolved Oxygen

In natural and waste waters, D.O level depends on the Physical, Chemical and Biological activity of water body. It indicates the organic pollution in water. Dissolved Oxygen is measured using Winkler's method.

When Manganous Sulphate is added to the sample containing alkaline Potassium Iodide, Manganous Hydroxide is formed, which is oxidized by the Dissolved Oxygen of the sample to basic Manganic Oxide. On addition of Sulphuric Acid, the basic Manganic Oxide liberates Iodine equivalent to that of Dissolved Oxygen originally present in the sample. The liberated Iodine is titrated with a standard solution of Sodium Thiosulphate using Starch as the indicator.

$MnSO_4- + 2KOH \longrightarrow Mn(OH)_2 + K_2SO_4$

$2Mn(OH)_2 + O_2 \text{ (D.O.)} \longrightarrow 2MnO(OH)_3$

(Basic Manganic Oxide, Brown in colour)

$MnO(OH)_2 + 2H_2SO_4 \longrightarrow Mn(SO_4)_2 + 3H_2O$

(Manganic Sulphate)

$Mn(SO_4)_2 + I_2 \longrightarrow MnS0_4 + K_2SO_4 + K_2SO_4 + I_2$

$2Na_2S_2O_3 + I_2 \longrightarrow Na_2S_40_6 + 2Nal$

Total Hardness

Temporary Hardness is due to the presence of Bicarbonate of Ca^{2+} and Mg^{2+} while Permanent Hardness is due to Sulphates, Chlorides of Mg^{+2} and Ca^{2+}. Besides these, Sr^{2+}, Fe^{2+} Mn^{2+}, HCO_3^{-} $S0_4^{=}$, CI^{-} and $SiO_3^{=}$ are also responsible for the Hardness of Water. The term "Total Hardness" indicates the concentration of Calcium and Magnesium Ions only. The Total Hardness is expressed in terms of Calcium Carbonate.

The analysis was done by complexometric titration. During, titration, Calcium and Magnesium Ions react with EDTA to form soluble complexes and the completion of reaction is indicated by the colour change of a suitable indicator such as Erichrome Black T.

$Ca^{2+} + H_2Y^{-} \longrightarrow Cay^{2-} + 2H^{+}$
(EDTA)
$Mg^{2+} + H_2Y^{2-} \longrightarrow Mgy^{2-} + 2H^{+}$

$MgD^{-} + H_2Y^{2-} \longrightarrow MgY^{2-} + HD^{2-} + H^{+}$
(Wine red) (Blue)

In this titration, Calcium Ions do not react with the indicator dye. Magnesium Ions only will react and change the colour of the dye. Therefore, a small amount of complexometrically neutral Magnesium Salt of EDTA is introduced to the titer through the addition of buffer (Wine red) to obtain end point (blue) by colour change of the indicator.

Acidity

Acidity of the water is its capacity to neutralize a strong base to a fixed pH. It is caused by the presence of strong mineral acid, weak acids and hydrolyzing salts of strong acids. However, in natural unpolluted fresh waters, the Acidity is mostly due to the presence of free CO_2 in the form of Carbonic Acid.

Acidity can be determined by titrating the sample with a strong base such as NaOH using Methyl Orange or Phenolphthalein as an indicator. If the sample has strong mineral acids and their salts, it is titrated first to pH 3.7, using Methyl Orange as an indicator and is called Methyl Orange Acidity. If the sample is titrated directly to pH 8.3, using Phenolphthalein, the resultant value is the Total Acidity.

Alkalinity

Alkalinity is the quantitative capacity of aqueous media to react with Hydrogen Ions. The Alkalinity of natural or treated water is normally due to the presence of Bicarbonate, Carbonate - and Hydroxide compounds of Calcium, Magnesium, Sodium and Potassium.

Alkalinity can be determined by titrating the strong alkali (such as Carbonate, free NaOH) to pH 8.3. At this pH all the free CO_2 is converted into Bicarbonates.

Chlorides

Silver Nitrate reacts with Chloride Ions to form Silver Chloride. The completion of reaction is indicated by the red colour produced by the reaction of Silver Nitrate with Potassium Chromate solution which is added as an indicator.

$AgNO_3 + Cl^- \longrightarrow AgCI\downarrow + NO_3^-$

$2AgNO_3 + K_2CrO_4 \longrightarrow Ag_2CrO_4\downarrow + 2KNO_3$

Biochemical Oxygen Demand (B.O.D.)

Biochemical Oxygen Demand (BOD) is the measure of the degradable organic material present in a water sample and can be defined as the amount of Oxygen required by the Micro Organisms in stabilizing the Biologically Degradable Organic matter under aerobic conditions.

The principle of the method involves, measuring the difference of the Oxygen concentration between the sample and after incubating it for five days at 20°C. Samples devoid of Oxygen or containing less amount of Oxygen are diluted several times with special type of dilution water saturated with Oxygen in order to provide sufficient amount of Oxygen for oxidation.

Chemical Oxygen Demand (C.O.D)

Chemical Oxygen Demand (COD) is the measure of Oxygen consumed during the oxidation of the oxidizable organic matter by a strong oxidizing agent. Potassium Dichromate in the presence of Sulphuric Acid is generally used as an oxidizing agent in determination of COD.

The sample is refluxed with $K_2Cr_2O_7$ and H_2SO_4 in presence of mercuric Sulphate to neutralize the effect of Chloride and Silver Sulphate (catalyst). The excess of Potassium Dichromate is titrated against Ferrous Ammonium Sulphate using Ferroin as Indicator. The amount of $K_2Cr_2O_7$ used is proportional to the oxidizable organic matter present in the sample.

Total Solids (TS)

Total Solids are determined as the residue left after evaporation of the unfiltered sample.

Total Dissolved Solids (TDS)

Total Dissolved Solids are determined as the residue left after evaporation of the filtered sample.

Sulphate

Sulphate Ion is precipitated in the form of Barium Sulphate by adding Barium Chloride in Hydrochloric Acid medium. The concentration of the Sulphate can be determined from the absorbance of the light by Barium Sulphate and then comparing it with a standard curve. Suspended matter and original colour of sample may interfere with the Sulphate determination. Suspended matter can be removed by filtration.

Nitrate

Nitrate reacts with Phenol Disulphonic Acid to form a Nitro Derivative which in alkaline medium develops a yellow colour. The concentration of $N0_3^-$ can be determined calorimetrically at 410nm. Since the colour so formed obeys the Beer's law.

Calcium

The presence of Calcium in water is mainly due to its passage through or over deposits of Lime Stone, Dolomite, Gypsum and other Gypsiferous Materials. Calcium and Magnesium are the two major scale-forming constituents in most raw water supplies.

Calcium can be determined by EDTA titrimetric method. In this method, the pH of the sample is made sufficient high (12-13) to precipitate Magnesium as Hydroxide and Calcium only is allowed to react with EDTA in the presence of a Murexide Indicator.

$Mg^{2+} + 2\ NaOH \longrightarrow Mg(OH)_2 + 2\ N\ a^{+}$

$Ca^{2+} + 2\ EDTA \longrightarrow Ca\ (EDTA)_2 + 2\ Na^{+}$

Magnesium

Calcium and Magnesium form a complex of wine red colour with Erichrome Black-T at high pH. The EDTA has got stronger affinity for Ca^{++} and Mg^{++} can be obtained by subtracting the value of Calcium from the total of Ca^{++} and $Mg^{++.}$

Iron

All the Iron is converted into Ferrous state by boiling with Hydrochloric Acid and Hydroxyl Amine. The reduced Iron Chelates with 1, 10-Phenonthroline at a pH 3.2 to 3.3 to form a complex of orange red colour. The intensity of this colour is proportional to the concentration of Iron and follows Beer's law, and therefore, can be determined colorimetrically at 510 nm .

Lead

Lead is made to react with Dithizone at a pH of about 11.5 to form Lead Dithizone which is soluble in Chloroform. In the presence of an Alkaline Cyanide solution, the free green coloured Dithizone is not extracted by Chloroform. The interference from Bismuth and Tin is eliminated by preliminary treatment of the sample with Dithizone at a pH about 2 to 3.

Zinc

Zinc reacts with Dithizone (Diphenyl Thiocarbazone) to form a coordinate compound which when extracted into Carbon Tetrachloride is red in colour and is used to measure the Zinc content.

Manganese

Manganese occurs in soils and rocks as Manganese Dioxide and can be dissolved in natural waters by the action of anaerobic bacteria. Under reducing conditions, Manganese can be leached from the soil and occurs in considerable concentrations in ground water.

Among the methods available for the determination of Manganese, the Persulphate method is the best suited and is applicable to all types of water. The soluble manganese compounds are oxidized to Permanganate by Persulphate in Acid solutions. The resulting colour of the Permanganate solution is measured spectrophotometrically at 545 nm.

Cadmium

Cadmium Ions react with Dithiozone to from a pink-red colour. The colour so formed is extracted with Choloroform and can be determined spectrophotometrically at 518 nm.

2.5 RESULTS AND DISCUSSION

Results of various water quality parameters of fourteen sampling stations with standard deviation of Bondamunda area of Rourkela Industrial Complex during March 1994 to February 1996 with seasonal variation are given in **Table 2.1** to **2.22** Phenols, Oil and Grease and Hexavalent Chromium were found to be absent in water of these fourteen sampling points.

Temperature

The Temperature of water samples ranged between minimum 16.42^0C at sampling station-3 (Sector-E Treated) during winter season to maximum 32.125^0C at sampling station 13 (Diesel Colony Treated) during summer season of 1994-95, where as in 1995-96, minimum 16.37^0C at sampling station -3 during winter season to maximum 32.65^0C at sampling station-13 during summer season (**Fig.2.1**). The Temperature of water samples, which may not be more important for public supply, but in the polluted water, it has profound effect on the dissolved oxygen, BOD and aquatic life. Water in the Temperature range of 7^0C to 11^0C has a pleasant taste and is refreshing. At higher Temperature, with less dissolved gases, the water becomes tasteless and even does not quench the thirst (Trivedy and Goel[112]-1986).

Turbidity

Turbidity is an expression of optical property of a water sample containing insoluble substances which cause light to be scattered rather than transmitted in straight lines. In most of the waters Turbidity is due to colloidal and extremely fine dispersions. Suspended matter such as clay, slit, finely divided organic and inorganic matter, plankton and other microscopic organisms also contribute to Turbidity (Manivaskam[48]-1986). The seasonal variation of Turbidity with standard deviation of fourteen sampling points during 1994-95 and 1995-96 are given in **Table 2.2**. It is observed that, the sampling points 1 to 14 except 8 and 9 meet the BIS (i.e. 10 N.T.U.) throughout the year while the value is higher than the standard during summer season of both the year. The population of the area mainly depends upon the Tube Well and Open Well water for domestic purposes as no treated water is available. In this area Turbidity has been found may be due to dust fall in the Open Well and maximum use of hand pump in case of Tube Well.

pH

Hydrogen ion concentration in water is the logarithmic reciprocal of their weights measured in grams per liter of water. In other words pH value of water is a measure of Acidity or Alkalinity of water and is very important indicator of its quality. It influences the growth of plants and soil organism, therefore, it affects to a great extent, the suitability of water for irrigation. The pH value of water is controlled by the amount of Bicarbonates, Carbonates and Dissolved Carbon dioxide. The pH varied from maximum 7.82 at sampling station-13 during summer season to minimum 6.43 at sampling station-12 during winter season of 1994-95 where as in 1995-96, maximum 7.78 at sampling station-13 during summer season to minimum 6.5 at sampling station 5and6 during rainy season (**Fig 2.3**). The pH value is less than 7.0 at seven sampling stations (Sector-B, Sector-D, Tilkanagar, Dumerta, Gundichapalli, Bortolli and Diesel Colony) of Tube Well water implying that the ground water in and around the study area is slightly acidic. The range of permissible limits as per BIS for portable water is 6.5 to 8.5. Higher values of pH hasten the scale formation in water heating apparatus and also reduce the germicidal potential of Chloride. The pH below 6.5 stands corrosion in pipes, thereby releasing toxic metals, such as Zn, Pb, Cd and Cu etc. pH has no direct adverse effect on human health, but lower value below 5.0 produce sour taste and higher value about 8.5 an alkaline test.

Conductance

Conductivity is a measure of capacity of substance or solution to conduct the electric current. It is a reciprocal of resistance. The Conductance varied from maximum 380.25 μmho/cm at sampling station 8 during summer season to minimum 160.25 μmho/cm at sampling station 3 during winter season of 1994-95, where as in 1995-96 maximum 419.5 μmho/cm at sampling station 8 during summer season to minimum 184.0 μmho/cm at sampling station 3 during summer season (**Fig. 2.4**). Almost all the Tube Well water samples exceeded the permissible limit (300 μmho/cm) except Gundichapalli due to the high concentration of Ionic constituents present in the water bodies under study and reflect the contributions from salinity intuition as well as pollution by domestic wastes. The Electrical Conductivity is due to mainly the dissolved ions such as Bicarbonates, Chlorides, Sodium, Potassium, Magnesium and Sulphate (Peavey[77] *et al.* 1986).

Dissolved Oxygen (D.O)

The D.O value ranged between 7.22 mg/l at sampling station 2 during winter season to 6.55 mg/l at sampling station 10 during summer season of 1994-95 where as in 1995-96 ranged between 7.17 mg/l at sampling station 2 during winter season to 6.55 mg/l at sampling station 3 during summer season (**Fig. 2.5**). The fluctuations in Oxygen content depend on factors such as Temperature, decompositional activities, photosynthesis and the level of aeration. D.O content was low in summer because of enhanced utilization by micro-organisms in the decomposition of organic matter. In summer the D.O depletion was due to high Temperature.

Total Hardness

Hardness is the property of water which prevents the leather formation with soap and increases the boiling point of water. Calcium and Magnesium are the principal cations causing Hardness. However other cations such as Strontium, Iron and Manganese also contribute to the Hardness. The anions responsible for Hardness are mainly Bicarbonate, Carbonate, Sulphate, Chloride, Nitrate, Silicates etc (Taylor[108] 1949). The Total Hardness varied from maximum 281.0 mg/l at sampling station 8 during summer season to 91.0 mg/l at sampling station 3 during winter season of 1994-95 whereas in 1995-96, ranged between 282.5 mg/l at sampling station 8 during summer season to 105.25 mg/l at sampling station 2 during winter season (**Fig. 2.6**). Higher values of Total Hardness are found in the Tube Well waters of Dumerta, Gundichapalli, Bortolli and Diesel Colony due to the presence of salts of Calcium and Magnesium. Hardness has no known adverse effects on health, however, some evidence has been given to indicate its role in heart diseases (Peter[78] 1974).

Acidity

Acidity of the water is its capacity to neutralize a strong base and is mostly due to the presence of strong mineral acids, weak acids (Carbonic, Acetic Acids) and the salts of strong acids and weak bases (e.g. Ferrous Sulphate, Aluminium Sulphate etc.) These salts on hydrolysis produce strong acid and metal hydroxides which are sparingly soluble thus producing the Acidity.

However in natural waters most of the acidity is present due to the dissolution of Carbon Dioxide which forms Carbonic Acid.

$CO_2 + H_2O \quad H_2CO_3$

Determination of Acidity is significant as it causes corrosion and influences the chemical and biochemical reactions (Kulkarni and Shrivastava[41]2000). The Acidity varied from maximum 31.0 mg/l at sampling station 5 during summer season to minimum 5.75 mg/l at sampling station 2 and 3 of 1994-95, where as in 1995-96, varied from maximum 29.0 mg/l at sampling station 7 during summer season to minimum 6.75 mg/l at sampling station 3 during rainy season (**Fig. 2.7**).

Alkalinity

Alkalinity is the capacity of water to neutralise the strong acid, depending upon the capacity of Hydroxyl Ions to combine with Hydrogen Ion.

$A^{-} + HOH \quad HA + OH^{-}$

Most of the Alkalinity of natural waters is formed due to dissociation of CO_2 in water :

$CO_2 + H_2O \quad H_2CO_3$
$H_2CO_3 \quad H^{+} + HCO_3^{-}$
$HCO_3^{-} \quad H^{+} + CO_3^{2-}$
$CO_3^{2-} + 2H_2O \quad H_2CO_3 + 2OH^{-}$

The constituents of Alkalinity in natural system mainly include Carbonate, Bicarbonate and Hydroxide. These constituents result from dissolution of mineral substances in the soil and atmosphere (Mittal and Verma[52] 1997). Carbonate and Biocarbonate may originate from microbial decomposition of organic matter also. The Alkalinity varied from maximum 217.5

mg/l at sampling station 7 during summer season to minimum 76.25 mg/l sampling station 2 during rainy season of 1994-95, where as in 1995-96 varied from maximum 215.75 mg/l at sampling station 7 during summer season to minimum 90.5 mg/l at sampling station 2 during rainy season (**Fig. 2.8**). Alkalinity of the areas like Tube Well water of Sector-D, Tilkanagar, Gundichapalli, Bortolli and Diesel Colony and Open Well water of Dumerta and Tilkanagar was found to be more than the permissible limit (120 mg/l). This may be due to the percolation of the domestic sewage of the area. The WHO acceptable limit for total Alkalinity is 200 mg/l. beyond this limit taste may become unpleasant.

Chloride

Chloride occurs naturally in all types of waters. The most important source of Chlorides in the waters is the discharge of domestic sewage. Man and other animals excrete very high quantities of Chlorides together with Nitrogeneous compounds. About 8-15 grams of NaCl is excreted by a person per day (Trivedy and Goel[112] 1986). Therefore, the Chloride concentration serves as an indicator of pollution by sewage. Industries are also important sources of Chlorides. The Chloride varied from maximum 196.34 mg/l at sampling station 5 (Sector D, Tube Well) during summer season to minimum 30.13 mg/l at sampling station 3 (Sector E, Treated) during winter season in 1994-95, where as in 1995-96, varied from maximum 168.38 mg/l at sampling station 7 (Tilkanagar, Open Well) during summer season to minimum 44.31 mg/l at sampling station 1 (Sector A, Treated) during rainy season (**Fig. 2.9**). The permissible limit of Chloride is 250 mg/l. All the sampling stations are within the limit. Chloride concentrations increases due to increase in mineral content and produces salty taste in water, at low 100mg/l concentration, Chloride is found in the form of Sodium, Potassium and Calcium salts. Chloride level of water indicates the pollutional degree of water. Higher values are hazardous to human consumption and create health problems (Kataria and Iqbal[37] 1995). People who are not accustomed to high Chloride in water are subjected to laxative effect as suggested by Raviprakash and Krishna Rao[92] (1989). The Chloride in the ground water may be contributed from minerals like Apatite, Mica, Hornblende and also from the liquid inclusions in the igneous rocks (Das and Malik[9] 1988).

BOD

Biochemical Oxygen Demand (BOD) is a test of great value in the analysis of sewage, industrial effluents and polluted waters. BOD refers to the quantity of Oxygen required by bacteria and other microorganisms in the biochemical degradation and transformation of organic matter under aerobic conditions (Manivaskasam[48] 1986). The basic principle for the determination of BOD is the measurement of the Dissolved Oxygen content of the sample before and after five days incubation at 20^0C. The BOD varied from maximum 5.425 mg/l at sampling station 7 (Tilkanagar, Open Well) during summer season to minimum 0.35 mg/l at sampling station 13 (Diesel Colony, Treated) during winter season in 1994-95, where as in 1995-96, varied from maximum 5.87 mg/l at sampling station-7 during summer season to minimum 0.38 mg/l at sampling station 13 during winter season (**Fig. 2.10**). BOD is within the limit as in case of ground water soil matrix acts as a biological filter consequently BOD is quite low.

COD

The Chemical Oxygen Demand (COD) varied from maximum 37.96 mg/l at sampling station 10 (Gundichapalli, Tube Well) during summer season to minimum 3.38 mg/l at sampling station 3 (Sector-E, Treated) during rainy season in 1994-95, where as in 1995-96, varied from maximum 34.84 mg/l at sampling station 10 during summer season to minimum 3.9 mg/l at sampling station 2 (Sector-C, Treated) during winter season (**Fig. 2.11**). COD was found to be high in Open Well waters during summer season due to the presence of oxidisable organic matter. The COD is an important parameter in management and design of the treatment plant because of its rapidity in determination. Its values are take as basis for calculation of the treatment plant (Trivedy and Goel[112] 1986).

Total Solids

Total Solids (T.S) are determined as the residue left after evaporation of the unfiltered sample. The Total Solids varied maximum 330.0 mg/l at sampling station 5 (Sector-D, Tube Well) during summer season to minimum 140.75 mg/l at sampling station 9 (Dumerta, Open Well) during winter season in 1994-95, where as in 1995-96, varied from maximum 318.0 mg/l at sampling station 8 (Dumerta, Tube Well) during summer season, to minimum 139.5 mg/l at sampling station 1 (Sector-A, Treated) during winter season (**Fig 2.12**). The values of Total Solids are within the prescribed limit (500 mg/l) of all the sampling stations in both the years.

Total Dissolved Solids

Total Dissolved Solids are determined as the residue left after evaporation of the filtered sample. The Total Dissolved Solids varied from maximum 288.25 mg/l at sampling station 5 (Sector D, Tube Well) during summer season to minimum 103.0 mg/l at sampling station 13 (Diesel Colony, Treated) during winter season in 1994-95, where as in 1995-96, varied from maximum 282.25 mg/l at sampling station 8 (Dumerta, Tube Well) during summer season to minimum 112.75 mg/l at sampling station 1 (Sector A, Treated) during winter season (**Fig. 2.13**). The Total Dissolved Solids were found due to the presence of various kinds of minerals in samples. Also organic substances, which are generally found in polluted water, may also contribute to the Dissolved Solids. Concentrations of Dissolved Solids, Suspended Solids are important parameter in water quality management. In industries, the use of water with high amount of Dissolved Solids may lead to scaling in boilers, corrosion and degradation of quality of product (Kulkarni and Shrivastava[41] 2000).

Sulphate

The Sulphate varied from maximum 30.45 mg/l at sampling station-9 (Dumerta, Open Well) during summer season to minimum 1.47 mg/l at sampling station 2 (Sector C, Treated) during rainy season in 1994-95, where as in 1995-96, varied from maximum 28.4 mg/l at sampling station 9 during summer season to minimum 1.34 mg/l at sampling station 3 (Sector E, Treated) during rainy season (**Fig. 2.14**). In all the sampling stations, the values of Sulphate are within the prescribed standard (200mg/l). The high concentration of Sulphate is due to oxidation of metal Sulphides, which is discharged by various industries. The most Sulphates are soluble in water except the Sulphates of Lead, Barium and Strontium. Daily intake of Sulphate from drinking water is poorly absorbed from the human intestine and slowly penetrates into the cellular membranes of mammals and is rapidly eliminated through the kidneys. The Sulphates of Sodium and Magnesium exert a cathartic action in human beings. It is also associated with respiratory diseases (Mohapatra and Singh[55] 1998).

Nitrate

The Nitrate varied from maximum 29.72 mg/l at sampling station 7 (Tilkanagar, Open Well) during summer season to minimum 1.57 mg/l at sampling station 13 (Diesel Colony, Treated) during rainy season in 1994-95, where as in 1995-96, varied from maximum 32-54 mg/l at sampling station 7 during summer season to maximum 1.51 mg/l at sampling station 13 during rainy season (**Fig. 2.15**). In all sampling stations the values of Nitrate are within the prescribed standard. The concentration of Nitrate Ion is very important in public water supplies because it causes methemoglobinemia in children (Naidu[66] *et al.* 1988). The presence of Nitrate indicates, the organic pollution of water and not only causes cyanosis among infants, when present in considerable quantity but also has been reported to course gastric cancer, when present in high quantity (Olaniya and Nawlakhe[69] 1978)

Calcium

The Calcium varied from maximum 190.35 at sampling station 8 (Dumerta, Tube Well) during rainy season to minimum 65.1 mg/l at sampling station 1 (Sector A, Treated) during winter season in 1994-95, where as in 1995-96, varied from maximum 196.61 mg/l at sampling station 10 during summer season to minimum 67.47 mg/l at sampling station 2 (Sector C, Treated) during winter season (**Fig 2.16**). The important sources of calcium in surface water are rain water, weathering of calcium silicate, minerals, irrigation, etc. The maximum desirable limit of Calcium in drinking water is 75 mg/l and maximum permissible limit is 200 mg/l. Calcium is an essential constituent of human being. The low content of Calcium in drinking water may cause ricket and defective teeth. It is essential for nervous system, cardiac function and in coagulation of blood (Khurshid[39] *et al*. 1998).

Magnesium

The Magnesium varied from maximum 98.07 mg/l at sampling station 8 (Dumenta, Tube Well) during summer season to minimum 23.65 mg/l at sampling station 1 (Sector A, Treated) during winter season in 1994-95, where as in 1995-96, varied from maximum 90.96 mg/l at sampling station 8 during summer season to minimum 31.6 mg/l at sampling station 9 (Dumerta, Open Well) during winter season (**Fig. 2.17**). The Concentration of Magnesium in water is comparatively less than the Calcium possibly due to lesser occurrence of Magnesium Minerals. Magnesium is moderately toxic element, if its concentration in drinking water is high. If high concentration of Mg is combined with Sulphate, laxative effect results, therefore, some caution must be exercised with it. Investigations have also shown in person living in hard water areas, Magnesium and Potassium are significantly increased in heart muscles, where as the ratio of Mg and K is usually low in person from soft water areas.

Iron

The Iron varied from maximum 0.93 mg/l at sampling station 4 (Sector B, Tube Well) during summer season to minimum 0.08 mg/l at sampling station 13 (Diesel Colony, Treated) during winter season in 1994-95, where as in 1995-96, varied from maximum 0.89 mg/l at sampling station 4 during summer season to minimum 0.09 mg/l at sampling station 13 during winter season (**Fig. 2.18**). Iron was relatively high in water samples of ground water due to the presence of underlying Iron Ore in the Rourkela area. The Treated water supplied from river Koel after primary treatment however as in the water comes from Iron Ore belt, the river water contains Iron concentrations much more than the permissible limit. Iron in excess of 0.3 mg/l causes staining of clothes and utensils. The water is also not suitable for processing food, beverages, ice, dyeing, bleaching etc. The limit on Iron in water is based on aesthetic and taste consideration rather than its physiological effects (Trivedy and Goel[112] 1986). Kakati and Bhattacharya[32] (1990) studied the water quality of various surface water sources of greater Gauhati and found that iron content ranges from 0.112 to 12.8 mg/l. John and Sarmah[29] (1997) on studying water samples from different sources of rural water supply of north Lakhimpur District of Assam and Papum Para District of Arunachal Pradesh, observed that Iron content was around 0.02 to 8.0 mg/l.

Lead

The Lead varied from maximum 0.073 mg/l at sampling station 6 (Tilkanagar, Tube Well) during summer season to minimum 0.021 mg/l at sampling stations 11 and 5 (R.S. Colony, Tube Well and Sector D, Tube Well) during winter season in 1994-95, where as in 1995-96, varied from maximum 0.079 mg/l at sampling station 6 during summer season to 0.018 mg/l at sampling station 5, during winter season. Lead is a cumulative poison and its effects on human health include gastrointestinal disorder, liver and kidney damage, abnormalities and infertility. Lead poisoning is due to permanent cumulative effects and not due to occasional exposure to small doses. However, in extreme case of lead poisoning death may result (Trivedy and Goel[112] 1986).

Zinc

The Zinc varied from maximum 1.261 mg/l at sampling station 6 (Tilkanagar, Tube Well) during summer season to minimum 0.182 mg/l at sampling station 2 (Sector C, Treated) during winter season in 1994-95, where as in 1995-96, varied from maximum 1.273 mg/l at sampling station 6 during summer season to minimum 0.199 mg/l at sampling station 2 during winter season (**Fig. 2.19**). Zinc in water produces undesirable effect and therefore the concentration of Zinc in public water supplies should be less than 5.0 mg/l. Water containing Zinc at concentrations in excess of 5.0 mg/l give an undesirable astringent taste (WHO, 1988) unsuitable for drinking and cooking purposes, and develop a greasy film on boiling and therefore this value is recommended as the guideline value. Water containing 4 mg/l of Zinc has a bitter or astringent test. (Cohen[8] 1960) Zinc is an essential element for human health. This deficiency in human body may results in infantilism, impaired wound healing and several other diseases (Khurshid[38] *et al.*, 1997).

Manganese

The Manganese varied from maximum 0.523 mg/l at sampling station 10 (Gundichapalli, Tube Well) during summer season to minimum 0.023 mg/l at sampling station 1 (Sector A, Treated) during winter season in 1994-95, where as in 1995-96 varied from maximum 0.465 mg/l at sampling station 10 during summer season to minimum 0.034 mg/l at sampling station 1

(**Fig. 2.20**). Manganese is an essential element, which does not occure naturally as a metal but is found in various salts and minerals frequently in association with Iron compounds. Higher levels of Manganese, sometimes found in freely flowing water are usually association with industrial pollution (Dwibedi and Tiwary[13] 1997). Manganese is found in all animals as a cofactor in a number of enzyme systems, it plays a role in the proper functioning of flyvoproteins and in the synthesis of Sulphated Mucopolysaccharides, Chlolesterol, Haemoglobin and in many other important metabolic process (WHO[117] 1988)

Cadmium

The Cadmium varied from maximum 0.0087 mg/l at sampling station 6 (Tilkanagar, Tube Well during summer season to minimum 0.0021 mg/l at sampling station 7 (Tilkanagar, Open Well) during winter season in 1994-95 where as in 1995-96, varied from maximum 0.0096 mg/l at sampling station 14 (Diesel Colony, Tube Well) during summer season to minimum 0.0026 mg/l at sampling station 7and9 (Open Well waters of Tilkanagar and Dumerta) (**Fig. 2.21**). The drinking water having more than 0.1 mg/l of Cadmium can cause bronchitis, emphysema, anaemia and real stone formation in animals (WHO[116] 1988). But in this study, all the values of Cadmium concentrations are found far below the limit and not harmful to use any purposes.

2.6 STATISTICAL ANALYSIS

The Correlation coefficient ‘r’ and regression coefficient value A and B for different environmentally significant water quality parameters were calculated using equations 1,2 and 3 :

$$r = \frac{N\Sigma XY - \Sigma X \Sigma Y}{\left[\left\{N\Sigma X^2 - (\Sigma X)^2\right\}\left\{N\Sigma Y^2 - (\Sigma Y)^2\right\}\right]^{\frac{1}{2}}} \qquad (1)$$

Where X and Y are two variables, N is the number of observations. In this case N=6 (average values of samples for each point was taken).

$$A = \frac{N\Sigma XY - \Sigma X\Sigma Y}{N\Sigma X^{2} - (\Sigma X)^{2}} \qquad (2)$$

$$B = \frac{1}{N}\ (\Sigma\, Y - A\,\Sigma\, X) \qquad (3)$$

From the values of A and B, Y values are calculated by using equation 4 :

$$Y = AX + B \qquad (4)$$

This is a linear equation for various water quality parameters. On the basis of the equations as cited above, an attempt has been made to complete the correlation coefficients for all possible linear relationships amongst the water quality parameters. The correlation coefficients (r values) for various water quality parameters of different sampling stations were presented in **Table 2.23** to **2.36**. The correlation coefficients (r values) for various sampling stations are discussed as follows.

Sector – A (Treated)

The highest positive correlation, r = 0.997 is found between Total Solids (T.S) and Total Dissolved Solids (TDS). This result indicates that, Total Dissolved Solids (TDS) is mainly due to Total Solids (TS). The highest negative correlation, r = - 0.952 is found between D.O and BOD. The larger the numerical values of the correlation coefficient (r = ±0.9), the greater is the extent to which, the linear correlation holds good between two variables. From **Table 2.23**, it is evident that, significant correlation exits between different parameters suggesting interrelationship in their gneiss and evolution, under the existing system of Physico-Chemical variabilities. From the correlation coefficients of water quality parameters, certain important linear relationships between them can be proposed as follows.

1. Turbidity = TDS x 13.46 + 86.19 (r = 0.947)

2. Turbidity = Cd x 0.00046 + 0.00344 (r = 0.956)

3. Conductance = TDS x 0.847 – 49.25 (r = 0.946)

4. D.O = BOD x (- 1.484) + 11.22 (r = - 0.952)

5. Total Hardness = Ca x 0.634 + 5.36 (r = 0.956)

6. Alkalinity = Cl x 1.37 – 90.53 (r = 0.956)

7. TS = TDS x 0.9505 – 23.27 (r = 0.997)

8. TS = Mn x 0.000798 + 85.15 (r = 956)

9. Mn = Cd x 0.03868 + 0.00324 (r = 0.981)

Like wise, serious combinations can be made. These linear equations are very much useful to calculate the other water quality parameters. The observed Total Solids (TS) and Total Dissolved Solids and Manganese and Cadmium values of the present system can be expressed with the help of equation (7) and (9) respectively. From various Total Solids (TS) and Manganese (Mn), the values of Total Dissolved Solids (TDS) and Cadmium (Cd) can be calculated respectively and compared with experimental results given in **Table 2.37**. The results are found to be in good agreement with a range of error from 0.17 to 3.09 % and 1.52 to 8.2 % for TDS and Cd respectively.

Sector C (Treated)

The highest positive correlation, r = 0.990 is found between temperature and pH and Calcium and Manganese (Mn). The highest negative correlation, r = - 0.962 is found between Temperature and Dissolved Oxygen (D.O). From the correlation coefficients of water quality parameters, certain important linear relationships between them can be proposed as follows.

1. Temperature = pH x 0.022 + 6.95 (r = 0.990)
2. Temperature = BOD x 0.0506 – 0.251 (r = 0.982)
3. Temperature = D.O x (-0.028) + 7.7 (r = - 0.962)
4. Total Hardness = Mg x 0.591 – 27.01 (r = 0.971)
5. BOD = Cd x 0.0035 + 0.0021 (r = 0.970)
6. Ca = Mn x 0.0045 – 0.264 (r = 0.990)

Like wise, serious combinations can be made. These linear equations are very much useful to calculate the other water quality parameters. From the equations (1) and (6) the various Temperature and Calcium, the values of pH and Manganese can be calculated respectively and compared with experimental results given in **Table 2.38**. The results are in good agreements. Hence the above equations are useful for the calculations of pH and manganese determining it experimentally.

Sector E (Treated)

The systematic calculation of correlation coefficient between water quality variables and regression analysis provide a rapid monitoring method and has been used in this study. The highest positive correlation (r = 0.988) is found between pH and Acidity. This indicates that, the pH in the Treated Water is mainly due to Acidity and Alkalinity. The highest negative correlation is observed between Temperature and Dissolved Oxygen (r = - 0.948) from the correlation coefficient of water quality parameters, certain important linear relationships between them can be proposed as follows.

1. Temperature = NO_3 x 0.082 + 1.568 (r = 0.987)
2. Temperature = D.O x (- 0.0306) + 7.66 (r = -0.948)

3. Turbidity = Ca x 1.451 + 64.15 (r = 0.982)

4. Turbidity = Fe x 0.024 + 0.0966 (r = 0.978)

5. Turbidity = Cd x 0.000404 + 0.00179 (r = 0.971)

6. pH = Acidity x 43.85 – 316.21 (r = 0.988)

7. Total Hardness = Mg x 0.712 – 38.65 (r = 0.976)

8. Ca = Fe x 0.016 – 0.937 (r = 0.970)

Similarly serious combinations can be made. These linear equations are very much useful to calculate other water quality parameters. The observed Temperature and Dissolved Oxygen (DO) values and pH and Acidity values of the present system can be expressed with the help of equation (2) and (6) respectively. From various Temperature and pH, the values of DO and Acidity can be calculated respectively and compared with experimental results given in **Table 2.39**. The results are found to be in good agreement with a range of error from 0.to 1.81 % and 0.003 to 16.55 % for DO and Acidity respectively.

Sector B (Tube Well)

The highest positive correlation (r = 0.991) is found between Total Hardness (TH) and Calcium, which indicates that, Total Hardness (TH) is mainly due to Calcium and Magnesium. The highest negative correlation (r = -0.943) is found between D.O and BOD. From the correlation coefficients of water quality parameters given in **Table 2.26**, certain important linear relationship between them can be proposed as follows.

1. Temperature = Acidity x 1.07 – 9.5 (r = 0.962)

2. Temperature = Fe x 0.0305 – 0.529 (r = 0.968)

3. pH = Cl x 238.9 – 1457.7 (r = 0.955)

4. DO = BOD x (-2.52) + 18.7251 (r = - 0.943)

5. Total Hardness = Ca x 0.598 + 12.65 (r = 0.991)

6. Total Hardness = Mg x 0.4025 – 12.82 (r = 0.983)

7. Acidity = Fe x 0.027 + 0.247 (r = 0.955)

8. Ca = Mg x 0.6459 – 18.45 (r = 0.951)

9. Mn = Cd x 0.00418 + 0.00495 (r = 0.968)

From the equation (4) and (5), the various DO and Total Hardness, the values of BOD and Calcium can be calculated respectively and compared with experimental results given in **Table 2.40** the results are in good agreements. Hence, the above equations are useful for the calculation of BOD and Calcium determining it experimentally.

Sector D (Tube Well)

The highest positive correlation (r = 0.989) is found between Total Solids (TS) and Total Dissolved Solids (TDS). The highest negative correlation (r = - 0.967) is found between DO and Sulphate (SO_4). From the correlation coefficients of water quality parameters, certain important linear relationships between them can be proposed as follows.

1. Temperature = Turbidity x 0.49 – 8.77 (r = 0.954)

2. Temperature = Conductance x 7.17 + 131.09 (r = 0.979)

3. Temperature = Mg x 0.917 + 19.58 (r = 0.969)

4. Turbidity = SO_4 x 0.9 + 10.424 (r = 0.955)

5. Turbidity = Fe x 0.0609 + 0.372 (r = 0.957)

6. pH = BOD x 5.33 – 33.874 (r = 0.984)

7. Conductance = Mn x 0.0045 – 1.168 (r = 0.977)

8. TS = TDS x 0.851 + 2. 255 (r = 0.989)

9. Turbidity = DO x (- 0.099) + 7.308 (r = - 0.964)

10. DO = SO_4 x (- 8.834) + 75.076 (r = - 0.967)

Like wise a serious of combinations can be made. These linear equations are very much useful to calculate the other water quality parameter. The observed TS and TDS values and D.O and Sulphate values of the present system can be expressed with the help of equation (8) and (10) respectively. From various TS and DO, the values of TDS and Sulphate can be calculated respectively and compared with experimental results given in **Table 2.41**. The results are found to be in good agreement with a range of error from 0.55 to 2.68 % and 0.43 to 4.71 % for TDS and Sulphate respectively.

Tilkanagar (Tube Well)

The highest positive correlation (r = 0.969) is found between Mn and Cd. The highest negative correlation is observed between Temperature and DO (r = - 0.955). The linear regression equations were computed for parameters having correlation coefficients values greater than 0.9 are given as follows.

1. Temperature = BOD x 0.126 – 1.79 (r = 0.940)
2. Temperature = Zn x 0.0469 – 0.123 (r = 0.946)
3. Temperature = DO x (-0.075) + 8.8555 (r = - 0.955)
4. Turbidity = Acidity x 1.475 + 8.787 (r = 0.938)
5. pH = BOD x 2.544 – 15.49 (r = 0.939)
6. Acidity = Fe x 0.0158 + 0.425 (r = 0.947)
7. Mn = Cd x 0.011286 + 0.00527 (r = 0.969)
8. DO = BOD x (-1.596) + 12.52 (r = - 0.929)

Similarly, a serious of combinations can be made. These linear equations are very much useful to calculate other water quality parameters. The observed Temperature and DO values and Manganese and Cadmium values of the present system can be expressed with the help of equations (3) and (7) respectively. From various Temperature and Manganese, the values of DO and Cadmium can be calculated and compared with experimental values and percentage of error can also be calculated given in **Table 2.42**. The results are in good agreements.

Tilkanagar (Open Well)

The highest positive correlation (r = 0.996) is found between conductance and Acidity. The highest negative correlation (r = - 0.971) is found between DO and Fe. The larger the numerical values of the correlation coefficient (r = ± 0.9), the greater is the extent to which, the linear correlation holds good between two variables. From the correlation coefficients of water quality parameters, the important linear relationships between them can be given as follows.

1. Temperature = Cl x 3.25 + 72.55 (r = 0.970)
2. Temperature = Mn x 0.0237 – 4.194 (r = 0.981)
3. Conductance = Acidity x 0.309 – 60.5 (r = 0.996)
4. Conductance = Cl x 0.696 – 27.84 (r = 0.975)
5. Conductance = BOD x 0.0556 – 15.07 (r = 0.995)
6. Total Hardness = NO_3 x 0.278 – 9.507 (r = 0.981)
7. Acidity = BOD x 0.175 + 0.921 (r = 0.975)
8. Chloride = Mn x 0.00714 – 0.7763 (r = 0.989)
9. TS = Cd x 0.000016 – 0.000705 (r = 0.977)
10. DO = Fe x (- 0.8028) + 5.832 (r = - 0.971)

Like wise, a serious of combinations can be made. These linear equations are very much useful to calculate the other water quality parameters.

Dumerta (Tube Well)

The highest positive correlation (r = 0.985) is found between Temperature and Turbidity. The highest negative correlation (r = - 0.901) is found between DO and Total Hardness (TH).

From the correlation coefficients of water quality parameters, certain important linear relationships between, certain important linear relationships between them can be given as follows.

1. Temperature = Turbidity x 1.358 – 25.33 (r = 0.985)
2. Turbidity = BOD x 0.159 – 0.26 (r = 0.944)
3. pH = COD x 33.797 – 209.944 (r = 0.949)
4. Total Hardness = Fe x 0.00977 + 178.78 (r = 0.918)
5. Acidity = Mg x 1.633 + 70.21 (r = 0.953)
6. Zn = Mn x 1.035 – 0.43 (r = 0.976)
7. DO = Total Hardness x (-32.395) + 1619.25 (r = - 0.901)

Dumerta (Open Well)

The highest positive correlation (r = 0.985) is found between Turbidity and Zinc. The highest negative correlation (r = - 0.957) is found between DO and COD. From the correlation coefficients of water quality parameters, certain important linear relationship between them can be given as follows.

1. Temperature = Turbidity x 0.786 + 13.005 (r = 0.968)
2. Temperature = Zn x 0.01338 – 0.010579 (r = 0.974)
3. Temperature = Mn x 0.02297 – 0.3266 (r = 0.981)
4. Turbidity = Fe x 0.01809 + 0.13028 (r = 0.974)
5. Turbidity = Zn x 0.01666 + 0.21318 (r = 0.985)
6. Fe = Cd x 0.00809 + 0.0010119 (r = 0.989)
7. Zn = Cd x 0.008707 + 0.00022 (r = 0.968)
8. DO = COD x (- 49.079) + 362.78 (r = - 0.957)

Gundichapalli (Tube Well)

The highest positive correlation (r = 0.996) is found between Total Hardness (TH) with Calcium and Magnesium. This indicates that, the Total Hardness in the Tube Well water is mainly due to Calcium and Magnesium salts. The highest negative correlation (r = - 0.970) is found between DO and manganese. From the correlation coefficients of water quality parameters, certain important linear relationship between them can be given as follows.

1. Temperature = COD x 4.22 – 89.34 (r = 0.967)
2. Turbidity = Mn x 0.1376 – 0.0607 (r = 0.963)
3. Conductance = TDS x 0.854 – 60.26 (r = 0.986)
4. DO = COD x (- 49.88) + 367.86 (r = - 0.953)
5. DO = Mn x (- 0.0269) + 0.12509 (r = - 0.970)
6. Ca = Mg x 0.915 – 103.77 (r = 0.986)
7. Total Hardness = Ca x 0.5186 + 55.014 (r = 0.996)
8. Total Hardness = Mg x 0.4811 – 54.915 (r = 0.996)
9. COD = Mn x 0.01288 + 0.0294 (r = 0.989)

R.S. Colony (Tube Well)

The highest positive correlation (r = 0.987) is found between Total Hardness and Calcium. This indicates that, Total Hardness (TH) is mainly due to Calcium and Magnesium salts. The highest negative correlation, (r = - 0.951) is found between Temperature and DO. From the correlation coefficient of water quality parameters, certain important linear relationship between them can be proposed as follows.

1. Temperature = DO x (- 0.036) + 7.972 (r = - 0.951)
2. Temperature = Turbidity x 0.729 – 15.74 (r = 0.952)

3. Conductance = COD x 0.290 – 74.786 (r = 0.952)

4. Total Hardness = Ca x 0.6097 + 14.21 (r = 0.987)

5. Total Hardness = Mg x 0.3902 – 14.2 (r = 0.969)

6. COD = Zn x 0.01849 + 0.779 (r = 0.971)

7. TS = Zn x 0.00706 – 0.7318 (r = 0.978)

8. TS = Mn x 0.00563 – 1.1934 (r = 0.986)

9. Ca = Zn x 0.01807 – 0.8703 (r = 0.968)

10. Zn = Mn x 0.763 – 0.574 (r = 0.966)

Bartoli (Tube Well)

The highest positive correlation (r = 0.986) is found between Chloride and Nitrate. The highest negative correlation (r = - 0.956) is found between DO and Nitrate. From the correlation coefficients of water quality parameters, certain important linear relationships between them are given as follows.

1. Temperature = Fe x 0.02347 – 0.0618 (r = 0.968)

2. Turbidity = BOD x 0.196 + 0.395 (r = 0.952)

3. Total Hardness = Ca x 0.532 + 31.89 (r = 0.983)

4. Cl = NO_3 x 0.077 + 7.255 (r = 0.986)

5. COD = NO_3 x 0.2008 + 12.615 (r = 0.951)

6. DO = NO_3 x (- 18.969) + 150.514 (r = - 0.956)

Diesel Colony (Treated)

The highest positive correlation (r = 0.981) is found between Temperature and BOD. The highest negative correlation (r = - 0.854) is found between Conductance and DO. From the correlation coefficients of water quality parameters, certain important linear relationships are given as follows.

1. Temperature = BOD x 0.061 – 0.853 (r = 0.981)

2. Turbidity = Cd x 0.00025 + 0.00188 (r = 0.969)

3. pH = Cl x 109.27 – 750.25 (r = 0.955)

4. BOD = SO_4 x 0.895 + 1.518 (r = 0.958)

5. Temperature = Cl x 2.857 + 12.69 (r = 0.948)

6. Cl = COD x 0.301 – 13.87 (r = 0.945)

Diesel Colony (Tube Well)

The highest positive correlation r = 0.988 is found between Turbidity and Total Hardness (TH). The highest negative correlation, (r = - 0.971) is found between DO and Total Hardness. From the correlation coefficient important linear relationship can be given as

1. Temperature = Turbidity x 0.302 – 5.396 (r = 0.975)

2. Temperature = Total Hardness x 3.554 + 121.689 (r = 0.985)

3. Turbidity = Total Hardness x 11.514 + 185.774 (r = 0.988)

4. TDS = NO_3 x 0.056 – 1.4108 (r = 0.970)

5. Ca = Fe x 0.0074 – 0.581 (r = 0.970)

6. Zn = Mn x 0.862 – 0.485 (r = 0.975)

7. DO = Total Hardness x (- 110.38) + 986.413 (r = - 0.971)

8. Temperature = DO x (-0.030) + 7.79 (r = - 0.961)

2.7 WATER QUALITY INDEX

Seasonal values for each parameter were calculated from monthly sample data. Out of 22 parameters studied 18 parameters were taken for calculating water quality index (Deininger and Maniciunas [14] 1971, Padmamavati[70] *et al.* 2003, Harkens[24] 1974, Tiwari and Ali[114] 1998, Naik and Purohit[61] 1996). A Water Quality Index (WQI) is defined as a rating reflecting the composite influence of different water quality parameters on the overall quality of water. The weights for various water quality parameters are assumed to be inversely proportional to the recommended standards for the corresponding parameters.

That is $W_i = {}^{K}\!/_{S_i}$ (1)

Where W_i = Unit weight for the ith parameters.

S_i = (I = 1,2,3 ………..18) refers to water quality parameters and
K = Constant of proportionality.

Calculation of WQI involves two fundamental steps:

1. Calculation of the quality rating for each of the water quality parameters used in the index and
2. Aggregation of these subindices into the overall index. The quality rating (or subindices) q_i corresponding to the parameter. q_i is a number of reflecting the relative value of this parameter in the polluted water with respect to its standard or permissible value. Quality rating may be obtained from

$q_i = 100\ [(V_i - V_{io}) / (S_i - V_{io})]$ (2)

Where V_i = Measured value of ith parameter in the polluted water under consideration.

V_{io} = The ideal value of this parameter in pure water.

S_i = Standard or permissible value for the ith parameter.

Since in general, the ideal value $V_{io} = 0$ for the drinking water for most parameter, equation (2) assumes the sample from for these parameters.

$q_i = 100\ (V_i/S_i)$ (3)

Equations (2) and (3) ensure that, $q_i = 0$, if the ith parameter is totally absent in the polluted water and $q_i = 100$, if the amount of this parameter is just equal to its permissible Si for the drinking water. But there are the following two exceptions.

a) For D.O : The ideal value may be taken as 14.6 mg/l (the solubility of Oxygen in pure water at 0^o C). Since the standard for drinking water is 5.0 mg/l, equation (2) reduces to

$q_{D.O} = 100 (V_{D.O} – 14.6) / (14.6 – 5.0)$ (4)

Where $V_{D.O.}$ is the observed value of Dissolved Oxygen.

b) For pH : The ideal value is 7.0 (for neutral water) and the permissible value is 8.5, so equation 2 for this case may be written as :

$q_{pH} = 100 (V_{pH} – 7.0) / (8.5-7.0)$ (5)

Where V_{pH} is the observed value of pH.

The overall arithmetic WQI is calculated by aggregating the quality rating q_i linearly.

$$\text{WQI} = \sum_{i=1}^{N}(qiWi) \;/\; \sum_{i=1}^{N}Wi$$

In the present study, eighteen water quality parameters namely Turbidity, pH, Conductance, D.O, Total Hardness, Alkalinity, Chloride, BOD, COD, Total Solids, Sulphate, Nitrate, Calcium, Magnesium, Iron, Zinc, Manganese and Cadmium were considered for computing WQI and unit weight (wi) of each parameter is obtained depending upon its weightage. The standard permissible values of various parameters for drinking purpose is considered as recommended by Indian Council of Medical Research (ICMR), World Health Organization (WHO) and Bureau of Indian Standards (BIS).

Chemical analysis of water gives a concept about its physical and chemical composition by some numerical values but for estimating exact quality of water, its better to depend on water quality index which gives the idea of quality of drinking water. The rating of WQI is shown below.

WQI level	**Water Quality Rating**
0-25	Excellent
26-60	Good
51-75	Poor
76-100	Very Poor
> 100	Unfit for Drinking Purposes.

The Water Quality Index (WQI) of fourteen sampling stations for two years (1994-95 and 1995-96) with different seasons were given in **Table 2.43**. From the above table, it is clear that, for Treated Water, the WQI varied from maximum 67.076 (Poor) at Sector-A during rainy season to minimum 24.89 (Excellent) at Diesel Colony during winter season in 1994-95 whereas in 1995-96 varied from maximum 70.426 (Poor) at Sector-A during rainy season to minimum 26.849 (excellent) at Diesel Colony during winter season. In Tube Well water the WQI varied from maximum 91.286 (Very Poor) to minimum 37.965 (Good) at Tilkanagar during summer season and R.S.Colony during winter season respectively in 1994-95 where as in 1995-96 varied from maximum 107.477 (Unfit for Drinking) to minimum 45.242 (Good) at Tilkanagar during summer season and R.S. Colony during winter season respectively. In Open Well water the WQI varied from maximum 42.098 (Good) at Dumerta during summer season to minimum 22.32 (Excellent) at Tilkanagar during winter season in 1994-95 where as in 1995-96 varied from maximum 48.594 (Good) at Tilkanagar during summer season to minimum 25.389 (Excellent) at Tilkanagar. The maximum value of WQI is obtained in Treated water during rainy season due to high turbidity water where as in Tube Well water the maximum value is obtained in summer season due to the lower ground water level and Iron is present in water because the position of Iron Ore in the ground level. The over all WQI as per Water Quality Rating for various study areas are given in **Table 2.44**.

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Table 2.1 Seasonal Variation of Temp in ^{0}C.

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	30.27 ± 3.58	23.22 ± 0.36	18.65 ± 3.11	31.23 ± 4.57	24.57 ± 0.81	17.22 ± 2.41
S_2	31.52 ± 2.71	23.57 ± 0.54	17.95 ± 2.92	30.93 ± 2.85	22.65 ± 1.46	16.98 ± 2.58
S_3	31.05 ± 3.53	23.47 ± 2.19	16.42 ± 4.31	32.12 ± 4.61	23.75 ± 1.27	16.37 ± 3.48
S_4	31.57 ± 3.09	23.67 ± 0.4	21.95 ± 0.51	31.65 ± 3.42	23.26 ± 0.54	22.58 ± 1.34
S_5	30.8 ± 4.17	25.07 ± 0.87	22.0 ± 0.76	31.5 ± 3.86	25.3 ± 0.74	21.26 ± 0.86
S_6	29.9 ± 5.82	25.1 ± 0.95	23.72 ± 3.05	30.2 ± 7.43	25.6 ± 1.57	22.08 ± 3.05
S_7	31.4 ± 3.17	24.5 ± 0.61	17.92 ± 2.59	30.15 ± 3.21	22.4 ± 0.78	18.19 ± 2.81
S_8	29.72 ± 5.58	25.37 ± 0.86	23.78 ± 2.91	30.42 ± 2.78	25.75 ± 0.94	23.27 ± 3.04
S_9	31.65 ± 3.24	24.47 ± 0.76	19.97 ± 1.65	30.45 ± 4.26	25.13 ± 0.85	18.91 ± 0.98
S_{10}	30.22 ± 5.02	24.85 ± 0.52	24.02 ± 2.87	29.54 ± 3.59	25.93 ± 0.35	23.58 ± 2.73
S_{11}	31.35 ± 2.82	24.95 ± 0.838	22.52 ± 0.419	30.27 ± 1.85	24.83 ± 0.62	23.35 ± 0.56
S_{12}	31.5 ± 2.94	24.92 ± 1.268	22.37 ± 0.499	30.65 ± 2.79	25.37 ± 0.58	22.45 ± 0.68
S_{13}	32.125 ± 12.768	24.5 ± 1.55	18.97 ± 1.46	32.65 ± 6.45	23.28 ± 1.28	19.83 ± 1.29
S_{14}	31.9 ± 2.95	24.7 ± 1.235	22.23 ± 1.49	31.45 ± 3.87	25.18 ± 0.38	22.13 ± 1.45

Table 2.2 Seasonal Variation of Turbidity in N.T.U.

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	3.25 ± 3.58	7.75 ± 3.86	2.25 ± 0.5	4.5 ± 3.02	7.25 ± 4.23	2.75 ± 0.87
S_2	3.75 ± 0.95	8.75 ± 5.12	2.5 ± 0.57	4.0 ± 2.65	9.5 ± 4.36	3.0 ± 0.68
S_3	4.75 ± 0.96	9.75 ± 6.55	1.25 ± 0.95	5.5 ± 1.62	10.25 ± 6.37	2.5 ± 0.54
S_4	4.2 ± 3.30	2.5 ± 1.0	2.0 ± 0.81	3.25 ± 2.65	2.5 ± 1.28	1.5 ± 0.87
S_5	6.5 ± 4.79	2.5 ± 0.57	1.5 ± 0.57	6.75 ± 5.21	4.0 ± 0.69	2.5 ± 0.62
S_6	7.0 ± 6.87	2.0 ± 0.81	2.25 ± 1.2	6.5 ± 4.83	2.25 ± 0.73	4.25 ± 0.52
S_7	7.75 ± 7.27	4.5 ± 1.41	2.5 ± 1.29	8.25 ± 6.85	3.0 ± 2.58	2.25 ± 1.16
S_8	15.0 ± 8.86	9.75 ± 3.3	6.5 ± 3.1	16.25 ± 7.45	8.5 ± 3.59	7.0 ± 4.27
S_9	10.5 ± 6.85	6.5 ± 5.9	1.5 ± 0.57	11.75 ± 5.65	8.0 ± 4.28	2.0 ± 1.63
S_{10}	4.5 ± 2.88	2.75 ± 2.21	1.5 ± 0.57	3.25 ± 2.37	2.75 ± 1.85	1.5 ± 0.73
S_{11}	6.75 ± 4.5	1.25 ± 0.5	1.75 ± 0.95	7.25 ± 3.73	2.0 ± 0.87	1.25 ± 0.84
S_{12}	3.25 ± 1.7	1.0 ± 0.816	1.25 ± 0.5	4.5 ± 2.04	1.25 ± 1.26	0.75 ± 0.48
S_{13}	4.25 ± 2.62	8.25 ± 4.68	2.5 ± 0.57	4.75 ± 3.71	9.25 ± 5.43	2.75 ± 0.87
S_{14}	4.5 ± 2.645	1.75 ± 0.5	1.25 ± 0.5	4.0 ± 1.84	2.0 ± 0.78	1.75 ± 0.62

Table 2.3 Seasonal Variation of pH

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	7.6 ± 0.27	7.3 ± 0.2	7.46 ± 0.15	7.62 ± 0.21	7.54 ± 0.05	7.37 ± 0.21
S_2	7.67 ± 0.25	7.48 ± 0.11	7.41 ± 0.12	7.65 ± 0.17	7.5 ± 0.18	7.29 ± 0.04
S_3	7.56 ± 0.05	7.37 ± 0.11	7.45 ± 0.24	7.72 ± 0.23	7.35 ± 0.21	7.52 ± 0.17
S_4	6.72 ± 0.16	6.65 ± 0.1	6.54 ± 0.25	6.8 ± 0.14	6.7 ± 0.07	6.53 ± 0.15
S_5	6.6 ± 0.2	6.46 ± 0.16	6.55 ± 0.21	6.73 ± 0.18	6.5 ± 0.26	6.6 ± 0.24
S_6	6.83 ± 0.05	6.7 ± 0.13	6.54 ± 0.34	6.92 ± 0.02	6.5 ± 0.31	6.62 ± 0.23
S_7	7.76 ± 0.04	7.38 ± 0.47	7.58 ± 0.15	7.72 ± 0.031	7.31 ± 0.27	7.59 ± 0.18
S_8	6.88 ± 0.08	6.45 ± 0.14	6.57 ± 0.18	6.87 ± 0.08	6.74 ± 0.24	6.53 ± 0.15
S_9	7.59 ± 0.17	7.26 ± 0.08	7.41 ± 0.08	7.56 ± 0.25	7.45 ± 0.06	7.34 ± 0.31
S_{10}	6.83 ± 0.08	6.56 ± 0.91	6.69 ± 0.91	6.92 ± 0.15	6.67 ± 0.38	6.75 ± 0.45
S_{11}	6.9 ± 0.13	7.23 ± 0.11	7.31 ± 0.03	7.15 ± 0.23	7.39 ± 0.16	7.51 ± 0.31
S_{12}	6.86 ± 0.29	6.71 ± 0.18	6.43 ± 0.17	6.81 ± 0.21	7.17 ± 0.25	6.96 ± 0.28
S_{13}	7.82 ± 0.17	7.66 ± 0.32	7.5 ± 0.17	7.78 ± 0.16	7.67 ± 0.19	7.42 ± 0.07
S_{14}	6.78 ± 0.14	6.67 ± 0.23	6.52 ± 0.01	7.04 ± 0.12	6.92 ± 0.27	6.8 ± 0.11

Table 2.4 Seasonal Variation of Conductance in μmho/cm

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	236.75 ± 25.39	245.0 ± 17.8	190.5 ± 11.41	244.5 ± 18.37	290.0 ± 24.54	192.5 ± 9.62
S_2	303.25 ± 20.74	283.0 ± 45.29	268.75 ± 26.31	270.25 ± 23.35	318.5 ± 30.17	242.25 ± 21.51
S_3	176.0 ± 28.31	252.0 ± 65.92	160.25 ± 5.62	184.0 ± 32.05	237.75 ± 17.88	195.0 ± 12.37
S_4	339.5 ± 8.96	366.5 ± 19.75	323.5 ± 20.8	311.25 ± 10.363	388.75 ± 15.45	335.5 ± 21.68
S_5	342.25 ± 19.05	316.0 ± 18.01	285.75 ± 25.06	362.25 ± 25.29	318.5 ± 12.57	280.5 ± 13.25
S_6	377.0 ± 16.55	344.0 ± 32.89	364.0 ± 14.3	360.25 ± 18.94	284.0 ± 32.57	252.5 ± 25.08
S_7	278.75 ± 10.51	247.0 ± 65.26	227.5 ± 11.47	288.0 ± 17.27	253.75 ± 21.26	245.5 ± 8.55
S_8	380.25 ± 40.47	362.0 ± 29.9	345.5 ± 7.37	419.5 ± 45.62	407.75 ± 32.27	379.75 ± 14.26
S_9	254.0 ± 12.64	236.25 ± 13.73	220.75 ± 8.99	295.75 ± 24.15	271.75 ± 12.29	257.5 ± 18.27
S_{10}	282.5 ± 2.38	295.75 ± 27.69	270.75 ± 13.93	321.75 ± 12.38	287.0 ± 18.92	274.5 ± 7.64
S_{11}	329.75 ± 18.00	313.75 ± 3.09	308.5 ± 34.57	345.5 ± 15.05	297.5 ± 5.72	270.75 ± 25.34
S_{12}	319.75 ± 28.91	337.75 ± 31.34	286.75 ± 21.62	325.25 ± 18.57	283.75 ± 20.34	277.5 ± 17.08
S_{13}	233.5 ± 24.95	215.75 ± 11.58	200.5 ± 8.69	243.25 ± 27.48	262.5 ± 18.71	201.75 ± 4.62
S_{14}	339.0 ± 45.12	364.0 ± 33.26	324.25 ± 8.65	382.5 ± 26.51	350.0 ± 15.06	331.25 ± 10.47

Table 2.5 Seasonal Variation of D.O in mg/l

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	6.65 ± 0.48	7.15 ± 0.06	7.17 ± 0.05	6.62 ± 0.57	7.12 ± 0.04	6.97 ± 0.03
S_2	6.8 ± 0.45	7.15 ± 0.05	7.22 ± 0.06	6.82 ± 0.25	7.05 ± 0.13	7.17 ± 0.05
S_3	6.82 ± 0.52	7.0 ± 0.05	7.15 ± 0.41	6.55 ± 0.41	6.93 ± 0.08	7.13 ± 0.02
S_4	6.96 ± 0.18	7.09 ± 0.1	7.17 ± 0.05	6.82 ± 0.28	7.15 ± 0.17	7.09 ± 0.21
S_5	6.72 ± 0.39	7.12 ± 0.05	7.1 ± 0.81	6.69 ± 0.23	6.85 ± 0.15	7.11 ± 0.17
S_6	6.5 ± 0.59	7.0 ± 0.05	7.12 ± 0.1	6.64 ± 0.36	7.02 ± 0.02	7.1 ± 0.06
S_7	6.65 ± 0.23	6.97 ± 0.15	7.05 ± 0.17	6.84 ± 0.45	6.98 ± 0.17	7.03 ± 0.03
S_8	6.62 ± 0.4	7.12 ± 0.05	7.05 ± 0.13	6.81 ± 0.97	7.15 ± 0.12	6.9 ± 0.18
S_9	6.72 ± 0.33	7.07 ± 0.12	7.0 ± 0.27	6.65 ± 0.17	7.03 ± 0.04	7.11 ± 0.02
S_{10}	6.55 ± 0.41	6.95 ± 0.13	7.17 ± 0.05	6.78 ± 0.24	7.00 ± 0.07	7.16 ± 0.11
S_{11}	6.825 ± 0.25	6.97 ± 0.44	7.2 ± 0.08	6.87 ± 0.37	7.05 ± 0.08	7.11 ± 0.06
S_{12}	6.92 ± 0.97	7.05 ± 0.13	7.07 ± 0.19	6.98 ± 0.86	7.12 ± 0.24	7.15 ± 0.08
S_{13}	6.87 ± 0.26	7.05 ± 0.13	7.15 ± 0.19	6.73 ± 0.48	6.86 ± 0.16	7.08 ± 0.13
S_{14}	6.8 ± 0.25	7.0 ± 0.08	7.16 ± 0.17	6.87 ± 0.31	6.98 ± 0.05	7.12 ± 0.03

Table 2.6 Seasonal Variation of Total Hardness in mg/l

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	128.5 ± 17.56	106.75 ± 15.88	88.25 ± 13.74	155.25 ± 15.83	142.0 ± 6.45	135.75 ± 14.63
S_2	118.25 ± 10.07	135.5 ± 11.12	91.75 ± 8.65	126.5 ± 12.37	138.25 ± 6.45	105.25 ± 8.92
S_3	105.75 ± 22.24	129.25 ±16.99	91.0 ± 9.69	124.0 ± 18.42	142.25 ± 12.93	110.5 ± 6.76
S_4	151.0 ± 17.14	168.25 ± 4.03	142.0 ± 5.71	164.5 ± 10.72	189.75 ± 9.54	141.25 ± 2.98
S_5	147.0 ± 10.42	137.25 ± 4.11	128.25 ± 3.4	168.25 ± 5.17	151.0 ± 8.23	148.25 ± 4.58
S_6	153.0 ± 2.44	161.25 ± 10.43	148.0 ± 5.35	156.5 ± 4.58	148.5 ± 8.67	140.25 ± 3.36
S_7	141.5 ± 8.34	130.25 ± 5.73	125.75 ± 1.5	148.5 ± 12.35	141.5 ± 7.85	132.75 ± 3.7
S_8	281.0 ± 12.19	271.75 ± 9.91	250.25 ± 3.86	282.5 ± 15.27	268.75 ± 8.42	259.0 ± 4.53
S_9	181.0 ± 3.55	163.75 ± 13.5	156.0 ± 6.37	167.25 ± 4.95	152.5 ± 6.48	143.75 ± 2.65
S_{10}	245.0 ± 10.42	232.25 ± 2.62	224.75 ± 3.4	273.25 ± 12.26	264.0 ± 5.92	236.5 ± 3.61
S_{11}	164.5 ±10.72	151.25 ± 2.75	144.0 ± 3.36	165.5 ± 8.45	157.25 ± 3.17	131.5 ± 2.74
S_{12}	211.5 ± 9.39	188.0 ± 6.78	174.25 ± 3.4	235.5 ± 12.67	206.25 ± 6.68	214.5 ± 3.84
S_{13}	141.25 ± 2.98	136.25 ± 3.5	131.75 ± 4.37	133.0 ± 4.21	128.5 ± 3.84	111.25 ± 2.05
S_{14}	238.0 ± 8.04	208.25 ± 4.71	198.0 ± 5.59	230.0 ± 5.65	212.0 ± 6.27	203.5 ± 2.29

Table 2.7 Seasonal Variation of Acidity in mg/l

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	19.0 ± 5.7	7.0 ± 2.16	12.5 ± 1.73	15.25 ± 3.42	8.75 ± 3.27	13.75 ± 2.5
S_2	16.25 ± 2.62	5.75 ± 1.7	13.5 ± 3.41	17.25 ± 4.47	13.75 ± 1.64	9.25 ± 1.2
S_3	15.25 ± 6.18	5.75 ± 1.7	9.25 ± 2.21	20.75 ± 5.86	6.75 ± 2.3	16.0 ± 1.74
S_4	25.25 ± 7.8	14.0 ± 2.8	15.5 ± 1.2	23.5 ± 5.21	16.25 ± 3.8	13.5 ± 1.52
S_5	31.0 ± 2.58	14.5 ± 4.28	20.75 ± 2.5	28.25 ± 3.75	14.0 ± 4.16	19.25 ± 2.68
S_6	19.25 ± 4.99	12.0 ± 8.64	10.25 ± 7.41	18.5 ± 6.58	14.0 ± 1.78	14.5 ± 4.94
S_7	25.5 ± 5.0	15.0 ± 2.58	10.5 ± 3.41	29.0 ± 4.37	17.5 ± 2.15	15.5 ± 3.89
S_8	16.0 ± 3.91	5.75 ± 1.7	11.25 ± 4.99	13.75 ± 2.65	8.5 ± 4.19	8.0 ± 1.54
S_9	25.0 ± 5.29	21.0 ± 2.25	22.5 ± 5.56	20.5 ± 3.51	17.75 ± 1.67	16.5 ± 2.34
S_{10}	16.25 ± 3.5	6.5 ± 1.29	14.25 ± 2.21	15.75 ± 4.65	11.0 ± 2.32	13.5 ± 1.68
S_{11}	14.5 ± 1.29	7.25 ± 2.21	10.25 ± 4.64	14.75 ± 3.27	9.25 ± 1.84	15.5 ± 2.26
S_{12}	13.0 ± 4.39	6.25 ± 3.6	10.0 ± 1.63	18.75 ± 3.46	9.5 ± 2.4	15.25 ± 1.72
S_{13}	13.75 ± 1.7	9.25 ± 2.21	11.0 ± 1.41	14.25 ± 4.29	11.0 ± 2.67	11.25 ± 1.18
S_{14}	25.5 ± 3.91	18.75 ± 2.7	21.5 ± 5.68	21.5 ± 2.4	14.0 ± 3.54	20.5 ± 3.87

Table 2.8 Seasonal Variation of Alkalinity in mg/l

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	122.0 ± 8.91	103.75 ± 6.87	93.5 ± 3.02	118.5 ± 7.52	89.25 ± 4.38	102.75 ± 2.07
S_2	103.25 ± 6.29	76.25 ± 4.19	86.25 ± 8.42	103.0 ± 8.26	90.5 ± 5.06	93.0 ± 7.42
S_3	116.25 ± 5.96	97.75 ± 3.2	108.0 ± 2.94	145.25 ± 3.45	112.5 ± 2.84	119.25 ± 6.57
S_4	151.75 ± 9.56	124.25 ± 7.13	134.75 ± 6.7	160.25 ± 8.64	131.5 ± 3.28	171.75 ± 9.54
S_5	166.25 ± 3.5	148.0 ± 9.5	156.25 ± 4.26	175.5 ± 6.21	160.25 ± 5.28	169.5 ± 3.36
S_6	147.75 ± 6.44	133.25 ± 6.39	140.25 ± 4.78	142.5 ± 5.17	134.25 ± 6.03	160.25 ± 8.16
S_7	217.5 ± 5.56	189.25 ± 4.35	203.75 ± 2.75	215.75 ± 6.08	183.25 ± 4.76	196.25 ± 3.89
S_8	105.5 ± 6.35	86.5 ± 1.29	93.5 ± 3.69	121.25 ± 4.28	110.5 ± 3.15	114.75 ± 2.84
S_9	208.0 ± 5.88	184.5 ± 7.04	192.5 ± 3.41	215.75 ± 6.77	186.0 ± 3.92	193.5 ± 4.45
S_{10}	138.5 ± 6.02	110.0 ± 6.73	119.5 ± 8.85	127.25 ± 5.41	98.5 ± 4.38	105.25 ± 2.17
S_{11}	107.5 ± 5.56	87.75 ± 3.09	96.0 ± 1.82	148.5 ± 3.46	125.25 ± 8.26	129.0 ± 1.47
S_{12}	164.5 ± 9.54	140.25 ± 5.56	147.0 ± 2.45	158.5 ± 6.12	135.0 ± 4.27	143.25 ± 2.58
S_{13}	116.75 ± 9.17	98.75 ± 4.34	108.75 ± 7.63	115.75 ± 8.61	103.25 ± 5.26	100.5 ± 3.18
S_{14}	149.25 ± 6.35	137.5 ± 6.05	142.75 ± 2.94	163.25 ± 8.69	128.5 ± 4.35	145.5 ± 2.61

Table 2.9 Seasonal Variation of Chloride in mg/l

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	63.81 ± 10.02	53.17 ± 4.09	44.31 ± 10.63	67.33 ± 14.79	44.31 ± 6.78	47.85 ± 19.52
S_2	109.89 ± 13.57	88.62 ± 6.89	72.67 ± 8.92	65.58 ± 26.76	49.63 ± 10.02	46.08 ± 9.15
S_3	60.26 ± 14.75	51.4 ± 6.78	30.13 ± 8.92	79.76 ± 17.62	70.68 ± 22.49	53.17 ± 9.15
S_4	148.89 ± 25.23	127.64 ± 15.34	99.26 ± 5.78	164.84 ± 34.43	140.02 ± 24.81	116.98 ± 9.15
S_5	196.34 ± 25.23	163.38 ± 16.84	175.64 ± 15.98	163.07 ± 27.76	154.2 ± 18.67	141.8 ± 22.23
S_6	138.25 ± 14.75	131.16 ± 9.15	93.94 ± 12.1	115.21 ± 31.37	102.8 ± 26.21	99.26 ± 28.94
S_7	173.7 ± 18.75	157.25 ± 12.24	134.71 ± 10.2	168.38 ± 21.94	147.11 ± 29.16	124.07 ± 16.87
S_8	168.38 ± 10.79	159.52 ± 9.15	136.48 ± 8.92	148.89 ± 19.65	134.71 ± 21.17	131.16 ± 9.15
S_9	165.42 ± 28.58	157.94 ± 7.65	149.89 ± 15.31	164.84 ± 10.63	147.11 ± 22.42	129.37 ± 15.68
S_{10}	134.8 ± 10.11	132.98 ± 6.86	101.03 ± 6.78	147.09 ± 18.64	124.07 ± 13.57	106.35 ± 8.18
S_{11}	186.11 ± 20.36	177.25 ± 10.02	168.38 ± 15.82	182.56 ± 8.92	159.52 ± 9.15	145.98 ± 5.78
S_{12}	145.34 ± 31.97	127.64 ± 15.34	116.98 ± 26.21	143.07 ± 19.21	111.41 ± 23.2	88.62 ± 9.15
S_{13}	101.03 ± 15.72	79.76 ± 6.78	67.35 ± 4.09	108.12 ± 6.78	88.62 ± 18.78	63.8 ± 10.03
S_{14}	168.38 ± 10.63	159.52 ± 9.15	136.48 ± 8.92	157.75 ± 20.36	131.16 ± 20.46	116.98 ± 12.28

Table 2.10 Seasonal Variation of BOD in mg/l

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	1.2 ± 0.2	0.95 ± 0.66	0.425 ± 0.26	1.5 ± 0.28	0.75 ± 0.62	0.625 ± 0.15
S_2	1.37 ± 0.498	0.84 ± 0.773	0.52 ± 0.28	1.32 ± 0.37	0.97 ± 0.45	0.75 ± 0.19
S_3	1.55 ± 0.73	0.475 ± 0.62	0.45 ± 0.53	1.35 ± 0.75	0.51 ± 0.58	0.72 ± 0.64
S_4	1.32 ± 0.32	0.725 ± 0.17	0.55 ± 0.19	1.47 ± 0.482	0.83 ± 0.162	0.91 ± 0.274
S_5	1.475 ± 0.42	0.85 ± 0.463	0.95 ± 0.136	1.97 ± 0.62	0.63 ± 0.27	1.15 ± 0.72
S_6	1.9 ± 0.29	1.45 ± 0.208	1.05 ± 0.36	2.2 ± 0.21	1.3 ± 0.264	1.18 ± 0.45
S_7	5.425 ± 0.74	3.9 ± 0.53	2.52 ± 0.31	5.87 ± 0.38	4.35 ± 0.42	3.34 ± 0.16
S_8	2.05 ± 0.49	1.0 ± 0.18	0.75 ± 0.36	2.52 ± 0.25	0.98 ± 0.21	1.21 ± 0.361
S_9	5.15 ± 1.2	3.45 ± 0.71	2.47 ± 0.61	5.7 ± 0.87	4.3 ± 0.42	3.7 ± 0.31
S_{10}	1.25 ± 0.33	0.7 ± 0.56	0.575 ± 0.78	1.95 ± 0.61	0.8 ± 0.21	1.54 ± 0.47
S_{11}	1.1 ± 0.244	0.775 ± 0.33	0.5 ± 0.562	1.52 ± 0.372	0.9 ± 0.42	1.27 ± 0.31
S_{12}	1.1 ± 0.316	0.6 ± 0.182	0.475 ± 0.171	1.24 ± 0.56	0.75 ± 0.38	0.56 ± 0.23
S_{13}	1.175 ± 0.263	0.625 ± 0.15	0.35 ± 0.129	1.12 ± 0.18	0.45 ± 0.34	0.38 ± 0.25
S_{14}	1.9 ± 0.658	1.0 ± 0.577	0.9 ± 0.637	1.85 ± 0.76	0.96 ± 0.22	1.6 ± 0.53

Table 2.11 Seasonal Variation of COD in mg/l

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	11.96 ± 4.05	3.64 ± 1.98	5.2 ± 3.6	17.16 ± 1.99	10.4 ± 4.49	5.72 ± 4.28
S_2	10.92 ± 4.28	5.72 ± 3.5	7.7 ± 5.57	13.0 ± 4.28	9.36 ± 4.32	3.9 ± 4.36
S_3	9.4 ± 2.94	3.38 ± 2.3	6.76 ± 3.93	9.36 ± 3.6	8.84 ± 3.55	4.16 ± 2.94
S_4	20.79 ± 0.33	3.9 ± 0.51	5.46 ± 3.32	15.08 ± 4.9	10.92 ± 7.28	6.24 ± 3.79
S_5	16.63 ± 8.48	3.9 ± 0.51	9.62 ± 8.11	20.8 ± 9.45	15.08 ± 8.38	11.96 ± 6.21
S_6	18.2 ± 5.97	7.28 ± 2.68	11.44 ± 7.3	31.74 ± 3.54	21.32 ± 13.3	14.16 ± 9.1
S_7	23.4 ± 8.38	17.16 ± 5.19	11.96 ± 8.88	26.0 ± 11.07	21.84 ± 14.05	8.84 ± 4.61
S_8	21.32 ± 4.61	8.32 ± 5.3	15.08 ± 3.55	23.4 ± 8.89	17.68 ± 9.68	7.8 ± 9.43
S_9	36.92 ± 3.93	15.6 ± 3.98	21.84 ± 6.00	32.76 ± 4.612	16.52 ± 7.47	12.34 ± 4.3
S_{10}	37.96 ± 5.2	20.8 ± 8.14	13.0 ± 4.91	34.84 ± 3.55	19.24 ± 8.56	5.72 ± 1.99
S_{11}	21.84 ± 3.6	13.0 ± 5.2	11.96 ± 4.61	27.04 ± 5.49	14.04 ± 2.68	4.68 ± 2.61
S_{12}	25.48 ± 3.12	21.32 ± 11.44	19.76 ± 7.87	32.4 ± 4.08	16.64 ± 8.82	8.84 ± 3.93
S_{13}	17.06 ± 2.16	8.22 ± 4.3	9.26 ± 5.1	19.76 ± 4.95	10.92 ± 4.91	4.68 ± 3.93
S_{14}	23.4 ± 8.72	9.36 ± 4.95	16.12 ± 2.61	26.01 ± 6.47	6.24 ± 2.94	13.52 ± 3.6

Table 2.12 Seasonal Variation of Total Solids in mg/l.

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	161.5 ± 15.8	218.25 ± 46.24	148.0 ± 10.36	201.75 ± 16.2	215.0 ± 35.47	139.5 ± 19.34
S_2	226.25 ± 39.39	235.0 ± 32.89	220.5 ± 58.36	206.5 ± 28.45	254.0 ± 42.67	188.5 ± 45.29
S_3	199.5 ± 36.73	270.0 ± 12.72	189.0 ± 33.79	193.0 ± 25.68	251.5 ± 38.5	168.0 ± 16.8
S_4	318 .25 ± 7.88	309.75 ± 10.3	290.5 ± 27.4	302.5 ± 12.47	256.25 ± 20.7	214.0 ± 24.16
S_5	330.0 ± 31.42	278.0 ± 32.46	254.25 ± 19.72	285.25 ± 33.62	248.0 ± 28.17	224.0 ± 15.3
S_6	264.5 ± 19.01	321.75 ± 38.74	300.5 ± 13.79	284.25 ± 21.17	338.0 ± 33.23	268.25 ± 15.45
S_7	219.25 ± 14.56	283.25 ± 85.95	178.25 ± 58.11	308.75 ± 23.79	265.0 ± 45.37	183.5 ± 38.27
S_8	280.75 ± 16.45	326.5 ± 16.78	279.75 ± 6.8	318.0 ± 20.4	293.5 ± 12.62	275.75 ± 26.45
S_9	176.75 ± 15.1	180.0 ± 15.12	140.75 ± 9.53	235.75 ± 17.4	212.5 ± 24.52	183.25 ± 12.67
S_{10}	220.25 ± 18.92	241.0 ± 27.41	211.75 ± 18.02	241.75 ± 16.6	228.5 ± 23.14	217.5 ± 21.57
S_{11}	270.5 ± 28.44	251.5 ± 8.1	232.0 ± 14.65	282.5 ± 32.45	258.75 ± 13.68	230.25 ± 18.19
S_{12}	264.5 ± 18.37	294.25 ± 18.22	241.25 ± 5.9	273.5 ± 24.32	247.25 ± 17.64	215.5 ± 10.84
S_{13}	166.75 ± 23.12	238.5 ± 64.69	150.5 ± 10.5	168.5 ± 19.27	228.25 ± 41.15	180.0 ± 8.24
S_{14}	326.5 ± 16.78	280.75 ± 16.45	279.75 ± 6.8	305.25 ± 20.27	265.5 ± 12.21	254.5 ± 8.74

Table 2.13 Seasonal Variation of Total Dissolved Solids in mg/l.

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	127.5 ± 11.95	184.5 ± 46.19	116.0 ± 10.09	167.25 ± 18.48	182.75 ± 31.26	112.75 ± 12.6
S_2	196.5 ± 38.76	180.75 ± 21.71	171.75 ± 25.73	162.0 ± 26.27	181.5 ± 30.42	146.0 ± 34.25
S_3	160.25 ± 30.71	219.75 ± 14.4	151.25 ± 30.53	118.5 ± 21.32	165.75 ± 16.26	136.5 ± 6.45
S_4	274.5 ± 12.68	254.25 ± 16.78	249.75 ± 30.13	220.75 ± 13.94	189.5 ± 12.37	175.0 ± 13.67
S_5	288.25 ± 28.5	232.5 ± 26.81	217.0 ± 20.6	242.0 ± 27.75	214.5 ± 26.48	197.5 ± 18.12
S_6	221.5 ± 18.3	267.0 ± 38.32	262.5 ± 13.57	245.25 ± 15.21	272.5 ± 6.45	225.0 ± 15.38
S_7	165.75 ± 16.39	210.0 ±73.93	131.5 ± 5.51	190.0 ± 20.91	185.75 ± 47.26	159.25 ± 10.5
S_8	237.0 ± 9.62	265.25 ± 10.43	237.25 ± 7.36	282.25 ± 16.17	261.0 ± 34.18	248.0 ± 4.64
S_9	138.75 ± 7.88	133.0 ± 12.35	113.0 ± 12.35	197.25 ± 8.43	181.0 ± 11.16	178.25 ± 13.2
S_{10}	179.25 ± 14.19	189.75 ± 23.45	175.25 ± 15.77	216.25 ± 12.63	185.0 ± 18.89	172.25 ± 8.67
S_{11}	226.25 ± 17.85	205.75 ± 7.04	196.75 ± 12.31	234.25 ± 13.19	224.5 ± 6.47	217.75 ± 12.28
S_{12}	217.5 ± 13.57	226.0 ± 18.49	197.25 ± 5.56	237.0 ± 14.28	205.25 ± 15.56	196.0 ± 7.47
S_{13}	119.75 ± 10.56	187.5 ± 53.79	103.0 ± 7.87	143.25 ± 12.67	170.0 ± 38.64	123.5 ± 12.49
S_{14}	265.25 ± 10.43	247.0 ± 9.62	227.25 ± 7.36	263.75 ± 13.67	240.51 ± 7.45	201.0 ± 11.62

Table 2.14 Seasonal Variation of Sulphate in mg/l.

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	2.9 ± 0.14	2.0 ± 0.5	2.52 ± 0.31	3.52 ± 0.56	1.65 ± 0.17	2.87 ± 0.54
S_2	2.57 ± 0.2	1.47 ± 0.21	2.17 ± 0.33	2.45 ± 0.34	1.85 ± 0.31	2.07 ± 0.26
S_3	2.92 ± 0.12	1.72 ± 0.25	2.27 ± 0.4	2.85 ± 0.26	1.34 ± 0.18	2.03 ± 0.33
S_4	3.87 ± 0.36	2.72 ± 0.72	3.47 ± 0.44	4.73 ± 0.24	2.65 ± 0.45	1.29 ± 0.57
S_5	16.47 ± 0.37	11.65 ± 4.5	12.3 ± ± 0.18	16.2 ± 0.26	14.7 ± 0.72	12.6 ± 0.26
S_6	9.17 ± 0.22	7.32 ± 0.55	8.4 ± 0.31	11.45 ± 0.12	8.27 ± 0.63	9.32 ± 0.45
S_7	19.32 ± 0.56	16.37 ± 1.27	18.05 ± 0.59	22.3 ± 1.34	17.4 ± 0.67	18.5 ± 0.49
S_8	14.9 ± 0.31	12.3 ± 1.11	13.57 ± 0.42	17.21 ± 0.92	12.53 ± 0.87	14.03 ± 0.58
S_9	30.45 ± 0.28	24.1 ± 0.65	27.37 ± 0.37	28.4 ± 0.75	23.5 ± 0.46	25.2 ± 0.64
S_{10}	3.0 ± 0.18	1.7 ± 0.18	2.37 ± 0.27	3.15 ± 0.21	2.37 ± 0.16	1.83 ± 0.27
S_{11}	4.62 ± 0.09	3.6 ± 0.31	4.17 ± 0.09	4.57 ± 0.25	3.19 ± 0.21	3.45 ± 0.18
S_{12}	9.37 ± 0.17	8.27 ± 0.17	8.12 ± 0.54	8.45 ± 0.68	6.27 ± 0.35	8.06 ± 0.46
S_{13}	2.6 ± 0.29	2.15 ± 0.28	1.67 ± 0.3	2.45 ± 0.37	2.01 ± 0.25	1.9 ± 0.31
S_{14}	13.62 ± 0.44	11.95 ± 1.0	10.47 ± 1.17	13.43 ± 0.76	11.18 ± 0.95	9.89 ± 0.65

Table 2.15 Seasonal Variation of Nitrate in mg/l

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	4.72 ± 0.17	3.5 ± 0.58	4.25 ± 0.62	4.67 ± 0.28	3.97 ± 0.35	3.78 ± 0.65
S_2	3.57 ± 0.51	2.25 ± 0.31	2.92 ± 0.13	3.8 ± 0.38	2.43 ± 0.46	3.08 ± 0.39
S_3	4.2 ± 0.29	3.62 ± 0.25	2.88 ± 0.41	4.05 ± 0.42	3.63 ± 0.27	2.85 ± 0.18
S_4	11.12 ± 0.33	10.67 ± 0.53	8.92 ± 0.62	10.14 ± 0.21	8.57 ± 0.37	7.45 ± 0.72
S_5	19.12 ± 0.45	16.77 ± 1.29	18.82 ± 0.87	17.78 ± 1.25	13.52 ± 0.38	15.59 ± 0.76
S_6	24.52 ± 0.17	20.25 ± 2.9	23.42 ± 0.17	23.25 ± 0.26	19.72 ± 1.87	21.53 ± 0.96
S_7	29.72 ± 0.88	27.12 ± 0.51	25.72 ± 1.15	32.54 ± 0.84	29.26 ± 1.38	27.36 ± 2.45
S_8	14.6 ± 0.29	11.35 ± 1.21	10.3 ± 0.39	12.27 ± 0.31	10.58 ± 0.27	8.71 ± 0.86
S_9	22.55 ± 0.19	20.7 ± 0.63	21.75 ±0.97	26.4 ± 0.25	24.2 ± 0.48	22.5 ± 1.16
S_{10}	18.82 ± 0.49	15.25 ± 0.12	14.15 ± 0.26	16.87 ± 0.67	13.52 ± 0.38	15.36 ± 0.94
S_{11}	10.0 ± 0.6	7.67 ± 0.63	9.05 ± 0.23	10.65 ± 0.24	8.47 ± 0.53	7.0 ± 0.37
S_{12}	18.525± 0.25	17.325 ± 0.22	16.175 ± 0.26	18.67 ± 0.61	15.54 ± 1.06	14.46 ± 0.45
S_{13}	3.12 ± 0.35	1.57 ± 0.17	2.2 ± 0.52	3.73 ± 0.34	1.51 ± 0.28	1.96 ± 0.39
S_{14}	13.35 ± 0.13	12.47 ± 0.27	11.63 ± 0.17	13.95 ± 0.25	11.67 ± 0.37	10.0 ± 0.76

Table 2.16 Seasonal Variation of Calcium in mg/l.

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	77.87 ± 2.01	71.4 ± 2.96	65.1 ± 2.94	106.5 ± 1.85	97.72 ± 2.67	93.2 ± 2.15
S_2	72.82 ± 2.64	80.5 ± 5.68	67.2 ± 1.72	79.58 ± 3.62	86.37 ± 4.54	67.47 ± 2.86
S_3	70.25 ± 1.26	77.35 ± 3.63	66.15 ± 1.21	71.3 ± 2.38	80.5 ± 2.76	68.7 ± 2.08
S_4	102.5±2.73	113.92 ± 7.36	96.3 ± 1.71	113.54 ± 5.16	124.85 ± 3.34	97.37 ± 1.67
S_5	100.27 ± 9.6	93.97 ± 3.58	88.72 ± 1.05	118.5 ± 6.5	112.32 ± 8.21	105.6 ± 2.48
S_6	130.52 ± 2.35	112.5 ± 2.01	102.85 ± 4.21	112.6 ± 3.28	108.35 ± 1.83	103.71 ± 2.13
S_7	80.32 ± 6.03	75.17 ± 5.52	73.35 ± 1.26	90.57 ± 5.17	82.35 ± 3.05	79.25 ± 1.92
S_8	182.87 ± 3.15	190.35 ± 4.21	161.8 ± 2.01	191.54 ± 3.28	183.3 ± 2.47	178.62 ± 2.29
S_9	131.77 ± 12.28	128.1 ± 14.03	115.5 ± 12.71	126.35 ± 6.44	120.9 ± 4.59	106.51 ± 12.68
S_{10}	180.6 ± 10.14	175.6 ± 8.34	171.77 ± 4.90	196.61 ± 13.42	192.64 ± 9.61	178.2 ± 4.07
S_{11}	116.02 ± 4.32	106.05 ± 1.21	102.9 ± 1.71	115.27 ± 3.17	107.84 ± 5.23	94.5 ± 2.39
S_{12}	146.4 ± 14.54	134.85 ± 3.63	122.75 ± 1.21	156.58 ± 12.6	139.34 ± 3.28	146.25 ± 4.64
S_{13}	94.57 ± 1.71	92.87 ± 2.01	89.82 ± 2.03	85.27 ± 3.49	83.38 ± 5.87	75.6 ± 3.43
S_{14}	163.22 ± 2.01	152.72 ± 4.02	133.25 ± 4.65	153.84 ± 3.08	142.21 ± 6.41	136.69 ± 2.65

Table 2.17 Seasonal Variation of Magnesium in mg/l.

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	50.62 ± 9.95	35.35 ± 14.99	23.65 ± 6.85	48.75 ± 12.73	44.28 ± 6.25	42.55 ± 5.64
S_2	45.42 ± 7.46	55.0 ± 7.8	24.55 ± 16.2	46.92 ± 8.46	51.58 ± 7.49	37.75 ± 13.25
S_3	35.5 ± 13.81	51.9 ± 13.5	24.85 ± 8.79	52.7 ± 12.19	61.75 ± 3.45	41.8 ± 7.86
S_4	48.45 ± 14.59	54.32 ± 3.86	45.7 ± 5.34	51.06 ± 13.82	64.9 ± 9.76	43.8 ± 4.28
S_5	46.72 ± 5.74	43.27 ± 4.43	39.52 ± 2.45	49.75 ± 3.87	41.68 ± 5.43	39.65 ± 6.49
S_6	40.72 ± 5.1	37.02 ± 10.03	45.15 ± 12.39	43.9 ± 7.45	40.15 ± 8.17	36.69 ± 10.28
S_7	61.17 ± 4.46	55.07 ± 5.68	53.4 ± 2.1	57.93 ± 3.49	59.15 ± 5.56	53.5 ± 3.49
S_8	98.07 ± 10.18	81.4 ± 8.91	88.4 ± 3.67	90.96 ± 8.45	85.45 ± 7.47	80.34 ± 4.52
S_9	49.22 ± 8.92	35.65 ± 4.71	40.5 ± 10.75	40.9 ± 7.48	31.6 ± 5.24	37.24 ± 9.72
S_{10}	64.4 ± 5.43	56.8 ± 2.21	52.97 ± 2.45	76.67 ± 7.25	71.39 ± 4.36	58.3 ± 3.85
S_{11}	48.47 ± 6.8	45.2 ± 1.65	41.1 ± 1.75	50.23 ± 4.58	49.41 ± 2.82	37.0 ± 1.46
S_{12}	65.1 ± 6.92	53.15 ± 7.78	51.5 ± 4.39	78.92 ± 6.45	66.93 ± 3.87	70.25 ± 1.58
S_{13}	46.75 ± 1.43	43.37 ± 1.82	41.92 ± 5.03	47.73 ± 2.39	45.11 ± 3.77	35.63 ± 6.65
S_{14}	74.77 ± 6.04	55.53 ± 1.14	64.75 ± 1.67	76.6 ± 3.28	69.79 ± 1.19	66.9 ± 1.87

Table 2.18 Seasonal Variation of Iron in mg/l.

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	0.175 ± 0.119	0.31 ± 0.211	0.23 ± 0.072	0.185 ± 0.085	0.26 ± 0.167	0.21 ± 0.097
S_2	0.25 ± 0.045	0.38 ± 0.037	0.14 ± 0.089	0.23 ± 0.069	0.3 ± 0.046	0.18 ± 0.114
S_3	0.18 ± 0.084	0.34 ± 0.145	0.16 ± 0.125	0.24 ± 0.56	0.34 ± 0.167	0.18 ± 0.086
S_4	0.93 ± 0.238	0.67 ± 0.134	0.59 ± 0.182	0.89 ± 0.138	0.72 ± 0.189	0.61 ± 0.142
S_5	0.77 ± 0.163	0.52 ± 0.115	0.41 ± 0.138	0.75 ± 0.118	0.67 ± 0.135	0.56 ± 0.169
S_6	0.72 ± 0.217	0.63 ± 0.145	0.56 ± 0.119	0.71 ± 0.194	0.65 ± 0.138	0.68 ± 0.085
S_7	0.48 ± 0.184	0.24 ± 0.112	0.14 ± 0.045	0.35 ± 0.157	0.28 ± 0.109	0.17 ± 0.036
S_8	0.88 ± 0.165	0.63 ± 0.123	0.53 ± 0.134	0.82 ± 0.136	0.67 ± 0.114	0.61 ± 0.157
S_9	0.31 ± 0.044	0.23 ± 0.118	0.14 ± 0.089	0.35 ± 0.036	0.29 ± 0.085	0.19 ± 0.045
S_{10}	0.52 ± 0.164	0.48 ± 0.137	0.43 ± 0.116	0.58 ± 0.168	0.45 ± 0.186	0.36 ± 0.138
S_{11}	0.63 ± 0.131	0.57 ± 0.144	0.41 ± 0.165	0.69 ± 0.136	0.48 ± 0.115	0.56 ± 0.162
S_{12}	0.67 ± 0.214	0.52 ± 0.158	0.44 ± 0.132	0.65 ± 0.154	0.58 ± 0.159	0.46 ± 0.097
S_{13}	0.23 ± 0.058	0.39 ± 0.072	0.08 ± 0.043	0.16 ± 0.038	0.35 ± 0.068	0.09 ± 0.034
S_{14}	0.65 ± 0.096	0.57 ± 0.134	0.43 ± 0.089	0.53 ± 0.093	0.48 ± 0.158	0.42 ± 0.086

Table 2.19 Seasonal Variation of Lead in mg/l.

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	n.d	n.d	n.d	n.d	n.d	n.d
S_2	n.d	n.d	n.d	n.d	n.d	n.d
S_3	n.d	n.d	n.d	n.d	n.d	n.d
S_4	0.035 ± 0.0119	0.025 ± 0.0086	0.029 ± 0.0127	0.032 ± 0.0094	0.028 ± 0.0087	0.026 ± 0.0108
S_5	0.034 ± 0.0077	0.027 ± 0.0126	0.021 ± 0.0118	0.039 ± 0.0085	0.033 ± 0.0154	0.018 ± 0.0078
S_6	0.073 ± 0.0125	0.062 ± 0.0145	0.054 ± 0.0161	0.079 ± 0.0117	0.067 ± 0.0169	0.058 ± 0.0096
S_7	n.d	n.d	n.d	n.d	n.d	n.d
S_8	0.035 ± 0.0112	0.047 ± 0.01224	0.028 ± 0.0072	0.032 ± 00.0084	0.053 ± 0.015	0.031 ± 0.0043
S_9	n.d	n.d	n.d	n.d	n.d	n.d
S_{10}	n.d	n.d	n.d	n.d	n.d	n.d
S_{11}	0.039 ± 0.0145	0.027 ± 0.0086	0.021 ± 0.0128	0.042 ± 0.0163	0.033 ± 0.0096	0.025 ± 0.0084
S_{12}	0.057 ± 0.0136	0.061 ± 0.0127	0.043 ± 0.0048	0.055 ± 0.0086	0.068 ± 0.0115	0.041 ± 0.0059
S_{13}	n.d	n.d	n.d	n.d	n.d	n.d
S_{14}	0.029 ± 0.013	0.032 ± 0.012	0.025 ± 0.0058	0.026 ± 0.038	0.037 ± 0.043	0.028 ± 0.0078

Table 2.20 Seasonal Variation of Zinc in mg/l.

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	0.213 ± 0.104	0.321 ± 0.165	0.162 ± 0.132	0.286 ± 0.009	0.416 ± 0.184	0.225 ± 0.152
S_2	0.252 ± 0.126	0.381 ± 0.155	0.182 ± 0.118	0.247 ± 0.135	0.393 ± 0.187	0.199 ± 0.106
S_3	0.297 ± 0.134	0.341 ± 0.151	0.257 ± 0.126	0.275 ± 0.163	0.357 ± 0.114	0.226 ± 0.346
S_4	0.745 ± 0.199	0.542 ± 0.145	0.652 ± 0.254	0.798 ± 0.203	0.464 ± 0.116	0.695 ± 0.215
S_5	0.924 ± 0.167	0.813 ± 0.216	0.741 ± 0.228	0.892 ± 0.0145	0.730 ± 0.0087	0.821 ± 0.00116
S_6	1.261 ± 0.258	1.142 ± 0.232	0.941 ± 0.221	1.273 ± 0.246	1.118 ± 0.203	0.875 ± 0.239
S_7	0.367 ± 0.176	0.482 ± 0.157	0.32 ± 0.126	0.476 ± 0.214	0.385 ± 0.115	0.371 ± 0.138
S_8	0.681 ± 0.192	0.72 ± 0.184	0.57 ± 0.145	0.643 ± 0.151	0.771 ± 0.197	0.514 ± 0.103
S_9	0.392 ± 0.155	0.304 ± 0.134	0.252 ± 0.124	0.421 ± 0.087	0.336 ± 0.125	0.245 ± 0.137
S_{10}	0.674 ± 0.128	0.542 ± 0.194	0.481 ± 0.167	0.735 ± 0.146	0.552 ± 0.135	0.481 ± 0.125
S_{11}	1.21 ± 0.187	1.06 ± 0.216	0.94 ± 0.195	1.26 ± 0.194	1.05 ± 0.177	0.87 ± 0.146
S_{12}	0.923 ± 0.195	0.985 ± 0.167	0.86 ± 0.206	1.13 ± 0.143	0.941 ± 0.118	0.832 ± 0.176
S_{13}	0.315 ± 0.151	0.392 ± 0.134	0.231 ± 0.126	0.365 ± 0.095	0.284 ± 0.116	0.213 ± 0.137
S_{14}	0.872 ± 0.158	0.92 ± 0.192	0.724 ± 0.178	0.863 ± 0.135	0.942 ± 0.174	0.715 ± 0.154

Table 2.21 Seasonal Variation of Manganese in mg/l.

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	0.054 ± 0.012	0.086 ± 0.017	0.023 ± 0.0053	0.068 ± 0.013	0.097 ± 0.018	0.034 ± 0.0061
S_2	0.063 ± 0.014	0.105 ± 0.018	0.036 ± 0.0092	0.087 ± 0.018	0.125 ± 0.011	0.043 ± 0.0085
S_3	0.052 ± 0.012	0.076 ± 0.0081	0.035 ± 0.0042	0.061 ± 0.0094	0.082 ± 0.012	0.038 ± 0.0054
S_4	0.192 ± 0.064	0.285 ± 0.042	0.093 ± 0.0075	0.213 ± 0.036	0.264 ± 0.045	0.145 ± 0.038
S_5	0.421 ± 0.025	0.342 ± 0.018	0.096 ± 0.011	0.431 ± 0.024	0.316 ± 0.015	0.112 ± 0.026
S_6	0.334 ± 0.045	0.216 ± 0.017	0.103 ± 0.034	0.326 ± 0.028	0.258 ± 0.014	0.157 ± 0.043
S_7	0.465 ± 0.018	0.351 ± 0.026	0.148 ± 0.047	0.425 ± 0.038	0.285 ± 0.016	0.132 ± 0.022
S_8	0.257 ± 0.038	0.346 ± 0.024	0.183 ± 0.012	0.214 ± 0.015	0.361 ± 0.034	0.095 ± 0.008
S_9	0.406 ± 0.047	0.245 ± 0.038	0.125 ± 0.026	0.387 ± 0.018	0.206 ± 0.016	0.128 ± 0.018
S_{10}	0.523 ± 0.019	0.324 ± 0.024	0.158 ± 0.031	0.465 ± 0.043	0.287 ± 0.021	0.115 ± 0.037
S_{11}	0.358 ± 0.054	0.217 ± 0.026	0.094 ± 0.0073	0.387 ± 0.014	0.253 ± 0.035	0.126 ± 0.023
S_{12}	0.415 ± 0.021	0.263 ± 0.014	0.157 ± 0.034	0.432 ± 0.038	0.125 ± 0.034	0.147 ± 0.018
S_{13}	0.084 ± 0.015	0.115 ± 0.025	0.036 ± 0.015	0.092 ± 0.012	0.125 ± 0.034	0.041 ± 0.0075
S_{14}	0.237 ± 0.042	0.316 ± 0.061	0.128 ± 0.018	0.254 ± 0.032	0.345 ± 0.018	0.153 ± 0.026

Table 2.22 Seasonal Variation of Cadmium in mg/l.

Sampling Stations	1994-1995			1995-1996		
	Summer	Rainy	Winter	Summer	Rainy	Winter
S_1	0.0050 ± 0.00181	0.0069 ± 0.00212	0.0045 ± 0.00164	0.0057 ± 0.00146	0.0071 ± 0.00246	0.0043 ± 0.00117
S_2	0.0053 ± 0.00192	0.0067 ± 0.00114	0.0038 ± 0.00167	0.0059 ± 0.00159	0.0065 ± 0.00158	0.0047 ± 0.00186
S_3	0.0031 ± 0.00081	0.0058 ± 0.00135	0.0027 ± 0.00095	0.0038 ± 0.00096	0.0062 ± 0.00146	0.0029 ± 0.00115
S_4	0.0061 ± 0.00184	0.0054 ± 0.00126	0.0048 ± 0.00221	0.0061 ± 0.00178	0.0067 ± 0.00132	0.0056 ± 0.00265
S_5	0.0074 ± 0.0023	0.0061 ± 0.00158	0.0053 ± 0.00167	0.0083 ± 0.00134	0.0073 ± 0.00175	0.0064 ± 0.00119
S_6	0.0087 ± 0.00236	0.0075 ± 0.00217	0.0064 ± 0.00171	0.0092 ± 0.00247	0.0085 ± 0.0022	0.0071 ± 0.00145
S_7	0.0037 ± 0.00083	0.0028 ± 0.00145	0.0021 ± 0.00080	0.0045 ± 0.00096	0.0033 ± 0.00136	0.0026 ± 0.00108
S_8	0.0063 ± 0.00145	0.0057 ± 0.00167	0.0048 ± 0.00192	0.0064 ± 0.00173	0.0058 ± 0.00183	0.0041 ± 0.00116
S_9	0.0037 ± 0.00085	0.0029 ± 0.00114	0.0022 ± 0.00077	0.0039 ± 0.00134	0.0030 ± 0.00186	0.0026 ± 0.00165
S_{10}	0.0072 ± 0.00195	0.0065 ± 0.00165	0.0057 ± 0.00178	0.0074 ± 0.00216	0.0061 ± 0.00172	0.0053 ± 0.00143
S_{11}	0.0052 ± 0.00161	0.0048 ± 0.00243	0.0035 ± 0.00168	0.0056 ± 0.00183	0.0052 ± 0.00147	0.0041 ± 0.00126
S_{12}	0.0084 ± 0.00187	0.0078 ± 0.00291	0.0065 ± 0.00243	0.0083 ± 0.00204	0.0075 ± 0.00286	0.0062 ± 0.00174
S_{13}	0.0029 ± 0.00187	0.0037 ± 0.00161	0.0025 ± 0.00132	0.0033 ± 0.00163	0.0043 ± 0.00158	0.0027 ± 0.00146
S_{14}	0.0082 ± 0.00194	0.0070 ± 0.00231	0.0063 ± 0.00219	0.0096 ± 0.00184	0.0083 ± 0.00158	0.0072 ± 0.00185

Table 2.23 Linear Correlation Coefficient for Water Quality Parameters for Sector A (Treated)

	Temp	Tur	pH	Cond.	DO	TH	Acidity	Alkalinity	Chloride	BOD	COD	TS	TDS	SO_4	NO_3	Ca	Mg	Fe	Zn	Mn	Cd
Temp	1.000	0.219	0.752	0.558	-0.779	0.546	0.831	0.721	0.856	0.924	0.845	0.475	0.425	0.363	0.694	0.381	0.710	-0.396	0.089	0.471	0.394
Tur		1.000	-0.220	0.812	0.797	0.159	-0.751	-0.264	0.194	0.198	-0.095	0.944	0.947	-0.656	-0.499	0.156	0.128	0.753	0.828	0.944	0.956
pH			1.000	0.614	-0.994	0.192	0.651	0.448	0.557	0.264	0.927	0.051	0.012	0.435	0.933	0.477	0.581	-0.737	-0.134	0.084	0.032
Cond.				1.000	-0.103	0.480	-0.396	-0.057	0.147	0.424	0.494	0.866	0.946	-0.458	0.00008	0.419	0.487	0.286	0.780	0.942	0.921
DO					1.000	-0.637	-0.836	-0.918	-0.913	-0.952	-0.824	0.095	0.145	-0.815	-0.811	-0.477	-0.784	0.823	0.390	-0.055	0.205
TH						1.000	0.288	0.386	0.474	0.603	0.515	0.615	0.299	0.358	0.312	0.956	0.883	-0.138	0.140	0.409	0.240
Acidity							1.000	0.736	0.615	0.412	0.565	-0.607	-0.624	0.898	0.836	0.132	0.449	0.461	0.757	-0.526	-0.633
Alkalinity								1.000	0.956	0.821	0.598	-0.071	-0.127	0.759	0.633	0.184	0.641	-0.626	-0.599	-0.065	-0.199
Chloride									1.000	0.941	0.743	0.163	0.145	0.737	0.668	0.305	0.659	-0.547	-0.364	0.129	0.009
BOD										1.000	0.175	0.425	0.399	0.501	0.519	0.481	0.744	-0.387	-0.064	0.412	0.290
COD											1.000	0.254	0.222	0.574	0.819	0.721	0.588	-0.673	0.048	0.256	0.150
TS												1.000	0.997	-0.427	-0.321	0.293	0.220	0.566	0.807	0.956	0.924
TDS													1.000	-0.433	-0.235	0.313	0.215	0.584	0.815	0.951	0.962
SO_4														1.000	0.671	0.320	0.358	-0.822	-0.723	-0.503	-0.618
NO_3															1.000	0.213	0.422	-0.847	-0.365	-0.234	-0.279
Ca																1.000	0.707	-0.351	0.242	0.362	0.205
Mg																	1.000	-0.501	-0.054	0.400	0.221
Fe																		1.000	0.617	-0.472	0.612
Zn																			1.000	0.799	0.770
Mn																				1.000	0.981
Cd																					1.000

Table 2.24 Linear Correlation Coefficient for Water Quality Parameters for Sector C (Treated)

	Temp	Tur	pH	Cond.	DO	TH	Acidity	Alkalinity	Chloride	BOD	COD	TS	TDS	SO_4	NO_3	Ca	Mg	Fe	Zn	Mn	Cd
Temp	1.000	0.055	0.990	0.484	-0.962	0.490	0.584	0.485	0.588	0.982	0.830	0.170	0.512	0.510	0.573	0.407	0.519	0.336	0.591	0.341	0.906
Tur		1.000	0.026	0.679	0.098	0.859	-0.379	-0.392	-0.083	0.048	-0.054	0.789	0.395	-0.739	-0.731	0.873	0.787	0.880	0.898	0.927	0.259
pH			1.000	0.643	-0.938	0.466	0.636	0.670	0.653	0.921	0.918	0.330	0.643	0.511	0.502	0.454	0.452	0.313	0.221	0.376	0.860
Cond.				1.000	-0.413	0.655	0.318	0.045	0.374	0.388	0.508	0.958	0.900	0.070	-0.266	0.728	0.555	0.581	0.731	0.717	0.573
DO					1.000	-0.376	-0.738	-0.656	-0.453	-0.778	-0.860	-0.023	-0.492	-0.700	-0.734	-0.304	-0.404	-0.126	-0.025	-0.222	-0.928
TH						1.000	-0.094	-0.060	0.037	0.535	0.289	0.591	0.376	-0.398	-0.238	0.944	0.971	0.895	0.906	0.960	0.681
Acidity							1.000	0.664	0.113	0.616	0.880	0.004	0.221	0.904	0.784	0.040	-0.184	-0.422	-0.321	0.365	0.493
Alkalinity								1.000	0.053	0.609	0.542	-0.269	0.009	0.723	0.711	-0.080	-0.042	-0.317	-0.329	-0.155	0.492
Chloride									1.000	0.443	0.303	0.243	0.801	0.251	0.210	-0.096	0.157	0.298	0.032	-0.086	0.364
BOD										1.000	0.795	0.072	0.128	0.572	0.579	0.420	0.583	0.298	0.178	0.357	0.970
COD											1.000	0.228	0.402	0.642	0.612	0.391	0.198	0.0002	0.032	0.276	0.711
TS												1.000	0.779	0.411	-0.585	0.704	0.468	0.628	0.796	0.721	0.229
TDS													1.000	0.026	-0.152	0.368	0.357	0.490	0.474	0.373	0.437
SO_4														1.000	0.942	-0.388	-0.376	0.622	-0.667	-0.434	0.377
NO_3															1.000	-0.346	-0.248	-0.530	-0.656	-0.467	0.434
Ca																1.000	0.838	0.780	0.896	0.990	0.571
Mg																	1.000	0.916	0.850	0.871	0.707
Fe																		1.000	0.924	0.842	0.139
Zn																			1.000	0.945	0.357
Mn																				1.000	0.526
Cd																					1.000

Table 2.25 Linear Correlation Coefficient for Water Quality Parameters for Sector E (Treated)

	Temp	Tur	pH	Cond.	DO	TH	Acidity	Alkalinity	Chloride	BOD	COD	TS	TDS	SO4	NO3	Ca	Mg	Fe	Zn	Mn	Cd
Temp	1.000	0.370	0.555	0.003	-0.948	0.338	0.441	0.526	0.752	0.814	0.694	0.167	0.105	0.546	0.987	0.079	0.361	0.278	0.378	0.445	0.169
Tur		1.000	-0.465	0.899	-0.284	0.917	-0.497	0.239	0.475	-0.180	0.003	0.917	0.613	-0.560	0.495	0.982	0.857	0.978	0.926	0.395	0.971
pH			1.000	-0.636	0.723	-0.271	0.988	0.917	0.446	0.939	0.452	-0.679	-0.770	0.881	0.480	-0.544	-0.150	-0.442	-0.557	-0.378	-0.598
Cond.				1.000	0.065	0.847	-0.602	-0.434	0.278	-0.451	-0.412	0.867	0.662	-0.771	0.140	0.909	0.790	0.942	0.753	0.844	0.928
DO					1.000	-0.376	-0.600	-0.771	-0.841	-0.698	-0.677	-0.027	0.351	-0.552	-0.559	0.052	-0.440	-0.248	-0.217	-0.389	-0.121
TH						1.000	-0.255	0.052	0.711	-0.128	0.015	0.713	0.305	-0.557	0.415	0.936	0.976	0.952	0.727	0.927	0.903
Acidity							1.000	0.891	0.449	0.794	0.393	-0.752	-0.813	0.635	0.279	-0.540	-0.129	-0.459	-0.631	-0.430	-0.623
Alkalinity								1.000	0.670	0.678	0.529	-0.523	-0.845	0.601	0.371	-0.260	0.177	-0.193	-0.394	-0.142	-0.326
Chloride									1.000	0.544	0.512	0.154	-0.293	0.128	0.718	0.496	0.772	0.522	0.322	0.585	0.388
BOD										1.000	0.688	-0.389	0.451	0.865	0.747	-0.251	-0.073	-0.258	-0.162	-0.118	-0.394
COD											1.000	0.164	-0.468	0.512	0.666	-0.019	0.030	-0.134	0.147	0.102	-0.119
TS												1.000	0.833	-0.624	0.328	0.088	0.616	0.879	0.944	0.889	0.932
TDS													1.000	-0.532	0.075	0.562	0.189	0.570	0.696	0.526	0.627
SO_4														1.000	0.434	-0.672	-0.491	-0.621	-0.478	-0.497	-0.718
NO_3															1.000	0.400	0.407	0.385	0.538	0.555	0.296
Ca																1.000	0.876	0.970	0.895	0.968	0.958
Mg																	1.000	0.910	0.631	0.829	0.839
Fe																		1.000	0.840	0.966	0.971
Zn																			1.000	0.918	0.891
Mn																				1.000	0.958
Cd																					1.000

Table 2.26 Linear Correlation Coefficient for Water Quality Parameters in Sector B (Tube Well)

	Temp	Tur	pH	Cond.	DO	TH	Acidity	Alkalinity	Chloride	BOD	COD	TS	TDS	SO_4	NO_3	Ca	Mg	Fe	Zn	Mn	Cd
Temp	1.000	0.891	0.851	-0.418	-0.916	0.025	0.962	0.380	0.850	0.948	0.887	0.577	0.397	0.754	0.685	0.097	-0.075	0.968	0.688	0.167	0.133
Tur		1.000	0.831	-0.099	-0.656	0.184	0.918	0.006	0.750	0.736	0.890	0.744	0.623	0.732	0.835	0.210	0.143	0.941	0.380	0.307	0.182
pH			1.000	0.050	-0.785	0.654	0.805	-0.018	0.955	0.810	0.764	0.569	0.197	0.752	0.654	0.716	0.549	0.932	0.196	0.656	0.362
Cond.				1.000	0.548	0.728	0.402	-0.612	-0.027	-0.407	-0.199	-0.168	-0.196	-0.459	-0.081	0.660	0.803	-0.197	-0.911	0.683	0.575
DO					1.000	0.013	-0.804	-0.519	-0.825	-0.943	-0.679	-0.419	-0.184	-0.670	-0.528	-0.091	0.161	-0.827	-0.755	-0.155	-0.034
TH						1.000	0.008	-0.511	0.492	0.048	0.092	0.095	-0.214	0.102	0.133	0.991	0.983	0.218	-0.637	0.848	0.523
Acidity							1.000	0.308	0.768	0.874	0.948	0.591	0.447	0.803	0.644	0.052	-0.052	0.955	0.645	0.041	0.134
Alkalinity								1.000	0.243	0.601	0.345	-0.430	0.403	-0.075	-0.297	0.450	0.586	0.254	0.761	-0.427	0.220
Chloride									1.000	0.892	0.765	0.366	0.046	0.574	0.519	0.564	0.376	0.902	0.324	0.565	0.462
BOD										1.000	0.848	0.288	0.081	0.570	0.445	0.131	-0.071	0.914	0.705	0.082	0.323
COD											1.000	0.400	0.290	0.608	0.502	0.113	0.062	0.936	0.509	0.091	0.413
TS												1.000	0.907	0.803	0.944	0.121	0.058	0.565	0.208	0.245	0.430
TDS													1.000	-0.913	0.852	0.217	0.200	0.365	0.214	-0.008	-0.520
SO_4														1.000	0.692	0.149	0.036	0.714	0.480	0.329	0.321
NO_3															1.000	0.173	0.074	0.687	0.240	0.408	0.218
Ca																1.000	0.951	0.270	-0.490	0.873	0.498
Mg																	1.000	0.138	-0.730	0.785	0.497
Fe																		1.000	0.505	0.312	0.310
Zn																			1.000	-0.521	-0.284
Mn																				1.000	0.968
Cd																					1.000

Table 2.27 Linear Correlation Coefficient for Water Quality Parameters in Sector D (Tube Well)

	Temp	Tur	pH	Cond.	DO	TH	Acidity	Alkalinity	Chloride	BOD	COD	TS	TDS	SO_4	NO_3	Ca	Mg	Fe	Zn	Mn	Cd
Temp	1.00	0.954	0.576	0.979	-0.918	0.658	0.713	0.452	0.790	0.715	0.674	0.833	0.822	0.867	0.360	0.322	0.969	0.860	0.759	0.941	0.830
Tur		1.00	0.691	0.919	-0.964	0.787	0.745	0.659	0.404	0.745	0.829	0.708	0.733	0.955	0.226	0.428	0.912	0.957	0.770	0.851	0.915
pH			1.00	0.532	-0.724	0.762	0.831	-0.526	0.153	0.984	0.853	0.233	0.263	0.672	0.399	0.405	0.665	0.560	0.669	0.463	0.625
Cond.				1.00	-0.908	0.695	0.583	0.406	0.405	0.662	0.644	0.746	0.716	0.816	0.234	0.372	0.970	0.835	0.665	0.977	0.860
DO					1.00	-0.800	-0.693	-0.671	-0.358	-0.710	-0.900	-0.606	-0.622	-0.967	-0.175	-0.465	-0.872	-0.904	-0.602	-0.703	-0.922
TH						1.00	0.443	0.876	0.337	0.591	0.891	0.174	0.192	0.794	0.239	0.628	0.714	0.816	0.516	0.628	0.027
Acidity							1.00	0.626	0.642	0.870	0.678	0.695	-0.738	-0.918	0.735	0.128	0.694	0.236	0.824	0.427	0.466
Alkalinity								1.00	0.096	0.777	0.882	0.073	0.144	0.691	0.076	0.484	0.490	0.645	0.554	0.247	0.670
Chloride									1.00	0.277	0.143	0.865	0.870	0.428	0.781	-0.254	0.408	0.246	0.444	0.424	0.060
BOD										1.00	0.692	0.495	0.501	0.092	0.371	0.299	0.804	0.586	0.831	0.470	0.603
COD											1.00	0.295	0.352	0.741	0.063	0.512	0.633	0.805	0.472	0.463	0.834
TS												1.00	0.989	0.622	0.641	-0.031	0.755	0.585	0.731	0.795	0.428
TDS													1.00	0.671	0.623	0.064	0.725	0.630	0.755	0.764	0.446
SO_4														1.00	0.177	0.424	0.776	0.928	0.616	0.735	0.877
NO_3															1.00	-0.295	0.375	-0.021	0.539	0.137	-0.129
Ca																1.00	0.525	0.483	0.178	0.325	0.569
Mg																	1.00	0.795	0.844	0.924	0.811
Fe																		1.00	0.685	0.829	0.933
Zn																			1.00	0.656	0.552
Mn																				1.00	0.256
Cd																					1.00

Table 2.28 Linear Correlation Coefficient for Water Quality Parameters in Tilkanagar (Tube Well)

	Temp	Tur	pH	Cond.	DO	TH	Acidity	Alkalinity	Chloride	BOD	COD	TS	TDS	SO_4	NO_3	Ca	Mg	Fe	Zn	Mn	Cd
Temp	1.00	0.745	0.811	0.655	-0.955	0.590	0.810	-0.198	0.647	0.940	0.613	0.234	-0.235	0.556	0.510	0.777	0.397	0.641	0.946	0.911	0.863
Tur		1.00	0.838	0.336	-0.889	0.073	0.938	0.505	0.455	0.819	0.631	-0.793	-0.803	0.783	0.719	0.672	0.195	0.844	0.552	0.706	0.647
pH			1.00	0.551	-0.685	0.552	0.789	0.160	0.435	0.939	0.520	-0.559	-0.518	0.831	-0.558	0.648	0.146	0.721	0.735	0.731	0.651
Cond.				1.00	-0.593	0.677	0.210	-0.381	0.528	0.518	0.091	-0.149	0.015	0.133	0.668	0.551	0.614	-0.038	0.598	0.330	0.203
DO					1.00	-0.453	-0.914	-0.074	-0.731	-0.929	-0.589	0.489	0.521	-0.566	-0.625	-0.894	-0.239	-0.778	-0.864	-0.901	-0.807
TH						1.00	0.149	-0.677	0.610	0.575	0.062	0.291	0.332	-0.062	0.004	0.462	0.088	0.092	0.757	0.496	0.412
Acidity							1.00	0.344	0.528	0.864	0.721	-0.577	-0.702	0.713	0.479	0.728	0.058	0.947	0.694	0.879	0.846
Alkalinity								1.00	-0.170	-0.022	0.050	-0.850	-0.876	0.420	0.379	-0.006	-0.243	0.426	-0.408	-0.124	-0.146
Chloride									1.00	0.640	-0.017	-0.183	-0.274	-0.049	0.213	0.883	-0.266	0.528	0.754	0.687	0.509
BOD										1.00	0.720	-0.360	-0.361	0.698	0.452	0.682	0.237	0.769	0.887	0.898	0.863
COD											1.00	-0.178	-0.178	0.860	0.264	0.196	0.452	0.613	0.559	0.682	0.806
TS												1.00	0.954	-0.578	-0.763	-0.364	0.048	-0.535	0.012	-0.157	-0.064
TDS													1.00	0.500	-0.612	-0.463	0.170	-0.685	-0.034	-0.274	-0.178
SO_4														1.00	0.528	0.130	0.430	0.618	0.340	0.477	0.557
NO_3															1.00	0.475	0.603	0.245	0.245	0.221	0.118
Ca																1.00	-0.029	0.640	0.769	0.783	0.620
Mg																	1.00	0.243	0.207	0.046	0.099
Fe																		1.00	0.580	0.823	0.657
Zn																			1.00	0.025	0.873
Mn																				1.00	0.969
Cd																					1.00

Table 2.29 Linear Correlation Coefficient for Water Quality Parameters in Tilkanagar (Open Well)

	Temp	Tur	pH	Cond.	DO	TH	Acidity	Alkalinity	Chloride	BOD	COD	TS	TDS	SO_4	NO_3	Ca	Mg	Fe	Zn	Mn	Cd
Temp	1.00	0.969	0.478	0.919	-0.915	0.761	0.903	0.612	0.970	0.679	0.884	0.612	0.480	0.556	0.796	0.603	0 .807	0.939	0.127	0.981	0.645
Tur		1.00	0.633	0.918	-0.878	0.733	0.919	0.755	0.923	0.907	0.821	0.558	0.365	0.705	0.804	0.638	0.684	0.864	-0.060	0.918	0.633
pH			1.00	0.540	-0.623	0.322	0.590	0.966	0.347	0.447	0.190	-0.207	-0.396	0.774	0.396	0.344	0.211	0.464	-0.774	0.315	0.043
Cond.				1.00	-0.828	0.923	0.996	0.612	0.975	0.995	0.841	0.595	0.432	0.754	0.947	0.844	0.768	0.872	0.190	0.853	0.677
DO					1.00	-0.641	-0.818	-0.706	-0.857	-0.785	-0.737	-0.255	-0.177	-0.489	-0.636	-0.429	-0.834	-0.971	-0.105	-0.864	-0.292
TH						1.00	0.922	0.391	0.657	0.944	0.851	0.630	0.215	0.713	0.981	0.943	0.784	0.753	0.177	0.708	0.685
Acidity							1.00	0.658	0.792	0.975	0.828	0.561	0.371	0.803	0.951	0.858	0.744	0.853	-0.010	0.825	0.655
Alkalinity								1.00	0.527	0.524	0.368	-0.048	-0.301	0.791	0.476	0.380	0.329	0.566	0.740	0.474	0.091
Chloride									1.00	0.882	0.896	0.655	0.512	0.421	0.697	0.477	0.786	0.890	0.206	0.989	0.650
BOD										1.00	0.910	0.684	0.533	0.670	0.953	0.834	0.839	0.895	0.201	0.904	0.734
COD											1.00	0.756	0.525	0.502	0.854	0.710	0.867	0.835	0.306	0.901	0.741
TS												1.00	0.883	0.276	0.684	0.620	0.423	0.407	0.664	0.686	0.977
TDS													1.00	-0.127	0.448	0.375	0.318	0.325	0.863	0.586	0.833
SO_4														1.00	0.792	0.818	0.323	0.454	-0.461	0.411	0.440
NO_3															1.00	0.960	0.040	0.728	0.126	0.736	0.761
Ca																1.00	0.537	0.529	0.083	0.525	0.716
Mg																	1.00	0.928	0.234	0.811	0.375
Fe																		1.00	0.085	0.912	0.417
Zn																			1.00	0.280	0.521
Mn																				1.00	0.539
Cd																					1.00

Table 2.30 Linear Correlation Coefficient for Water Quality Parameters in Dumerta (Tube Well)

	Temp	Tur	pH	Cond.	DO	TH	Acidity	Alkalinity	Chloride	BOD	COD	TS	TDS	SO_4	NO_3	Ca	Mg	Fe	Zn	Mn	Cd
Temp	1.00	0.985	0.865	0.605	-0.670	0.910	0.748	0.415	0.230	0.911	0.839	0.350	0.388	0.722	0.862	0.587	0.772	0.866	0.389	0.241	0.687
Tur		1.00	0.793	0.567	-0.714	0.923	0.710	0.404	0.243	0.944	0.749	0.392	0.411	0.756	0.839	0.372	0.713	-0.104	0.303	0.162	0.594
pH			1.00	0.685	-0.667	0.687	0.847	0.631	0.113	0.794	0.949	-0.061	0.159	0.689	0.705	0.289	0.833	0.859	0.289	0.102	0.624
Cond.				1.00	-0.232	0.653	0.251	0.836	-0.018	0.641	0.576	0.274	0.681	0.523	0.193	0.651	0.180	0.610	0.351	0.171	0.465
DO					1.00	-0.901	-0.832	0.462	-0.174	-0.804	-0.522	0.276	0.199	-0.745	-0.642	-0.161	-0.735	-0.782	0.268	0.412	-0.094
TH						1.00	0.448	0.353	0.246	0.818	0.591	0.521	0.523	0.509	0.778	0.850	0.513	0.918	0.552	0.416	0.730
Acidity							1.00	0.392	0.109	0.734	0.848	-0.273	-0.196	0.747	0.731	-0.062	0.953	0.728	-0.079	-0.214	0.323
Alkalinity								1.00	-0.094	0.632	0.480	-0.167	0.354	0.683	-0.009	0.294	0.190	0.486	0.180	0.372	0.015
Chloride									1.00	0.170	0.105	0.131	0.004	0.065	0.306	0.166	0.199	0.232	0.146	0.139	0.198
BOD										1.00	0.713	0.237	0.402	0.904	0.661	0.560	0.640	0.897	0.033	-0.132	0.354
COD											1.00	0.333	0.192	0.671	0.694	0.165	0.853	0.737	0.311	0.162	0.637
TS												1.00	0.837	0.078	0.199	0.725	-0.189	0.166	0.511	0.547	0.392
TDS													1.00	0.327	0.005	0.754	-0.233	0.235	0.362	0.315	0.294
SO_4														1.00	0.409	0.248	0.561	0.652	-0.303	-0.446	0.033
NO_3															1.00	0.375	0.864	0.846	0.465	0.376	0.736
Ca																1.00	-0.015	0.609	0.540	0.451	0.523
Mg																	1.00	0.748	0.170	0.056	0.536
Fe																		1.00	0.346	0.174	0.642
Zn																			1.00	0.976	0.916
Mn																				1.00	0.834
Cd																					1.00

Table 2.31 Linear Correlation Coefficient for Water Quality Parameters in Dumerta (Open Well)

	Temp	Tur	pH	Cond.	DO	TH	Acidity	Alkalinity	Chloride	BOD	COD	TS	TDS	SO_4	NO_3	Ca	Mg	Fe	Zn	Mn	Cd
Temp	1.00	0.968	0.756	0.487	-0.869	0.871	0.540	0.685	0.865	0.856	0.841	0.536	0.234	0.581	0.496	0.875	0.524	0 .907	0.974	0.981	0.946
Tur		1.00	0.684	0.701	-0.798	0.734	0.330	0.617	0.785	0.902	0.710	0.718	0.423	0.395	0.613	0.821	0.313	0.974	0.985	0.936	0.961
pH			1.00	0.544	-0.892	0.612	0.455	0.821	0.576	0.739	0.885	0.368	0.277	0.773	0.667	0.441	0.638	-0.684	0.779	0.721	0.721
Cond.				1.00	-0.548	0.099	0.339	0.577	0.195	0.870	0.325	0.959	0.932	0.098	0.918	0.180	-0.064	0.832	0.708	0.541	0.750
DO					1.00	-0.780	-0.572	-0.930	-0.791	-0.801	-0.957	-0.434	-0.236	-0.824	-0.629	-0.635	-0.701	-0.750	-0.885	-0.892	-0.856
TH						1.00	0.864	0.590	0.920	0.547	0.868	0.076	-0.246	0.730	0.081	0.906	0.755	0.588	0.755	0.886	0.722
Acidity							1.00	0.405	0.777	0.108	0.755	-0.390	-0.648	-0.759	-0.283	0.686	0.804	0.138	0.388	0.555	0.307
Alkalinity								1.00	0.555	0.765	0.866	0.407	0.344	0.845	0.648	0.356	0.724	0.617	0.729	0.757	0.763
Chloride									1.00	0.527	0.754	0.231	0.158	0.590	0.250	0.936	0.537	0.633	0.809	0.852	0.712
BOD										1.00	0.672	0.801	0.668	0.453	0.755	0.532	0.257	0.955	0.913	0.864	0.966
COD											1.00	0.193	-0.008	0.915	0.426	0.670	0.837	0.624	0.801	0.858	0.758
TS												1.00	0.903	-0.097	0.841	0.265	-0.247	0.830	0.688	0.510	0.715
TDS													1.00	-0.169	0.818	-0.142	-0.312	0.605	0.411	0.227	0.490
SO_4														1.00	0.226	0.397	0.963	0.315	0.518	0.645	0.519
NO_3															1.00	0.116	-0.005	0.720	0.673	0.461	0.639
Ca																1.00	0.408	0.679	0.787	0.789	0.719
Mg																	1.00	0.216	0.411	0.604	0.446
Fe																		1.00	0.958	0.873	0.989
Zn																			1.00	0.951	0.968
Mn																				1.00	0.960
Cd																					1.00

Table 2.32 Linear Correlation Coefficient for Water Quality Parameters in Gundichapalli (Tube Well)

	Temp	Tur	pH	Cond.	DO	TH	Acidity	Alkalinity	Chloride	BOD	COD	TS	TDS	SO_4	NO_3	Ca	Mg	Fe	Zn	Mn	Cd
Temp	1.00	0.911	0.719	0.605	-0.944	0.635	0.533	0.760	0.808	0.522	0.967	0.342	0.562	0.882	0.798	0.573	0.698	0.846	0.960	0.952	0.210
Tur		1.00	0.410	0.437	-0.984	0.467	0.235	0.644	0.809	0.262	0.934	0.372	0.375	0.650	0.768	0.402	0.535	0.767	0.824	0.963	0.482
pH			1.00	0.423	-0.523	0.578	0.878	0.642	0.397	0.842	0.559	0.010	0.454	0.829	0.648	0.539	0.612	0.512	0.735	0.501	-0.445
Cond.				1.00	-0.462	0.739	-0.003	0.225	0.869	0.562	0.621	0.893	0.986	0.456	0.294	0.730	0.746	0.814	0.776	0.630	0.282
DO					1.00	-0.443	-0.346	-0.749	-0.805	-0.373	-0.953	-0.342	-0.405	-0.705	-0.860	-0.374	-0.516	-0.793	-0.870	-0.970	-0.332
TH						1.00	0.271	0.139	0.685	0.588	0.548	0.553	0.738	0.625	0.174	0.996	0.996	0.603	0.725	0.552	0.305
Acidity							1.00	0.657	0.008	0.572	0.358	0.436	0.064	0.774	0.528	0.232	0.306	0.242	0.452	0.267	-0.607
Alkalinity								1.00	0.422	0.347	0.760	-0.050	0.246	0.746	0.857	-0.015	0.132	0.656	0.661	0.699	0.226
Chloride									1.00	0.457	0.863	0.822	0.810	0.541	0.575	0.648	0.725	0.896	0.893	0.901	0.503
BOD										1.00	0.362	0.011	0.533	0.489	0.570	0.569	0.602	0.369	0.632	0.362	0.433
COD											1.00	0.452	0.602	0.808	0.757	0.485	0.612	0.932	0.939	0.989	0.353
TS												1.00	0.876	0.082	0.111	0.557	0.551	0.641	0.538	0.511	0.552
TDS													1.00	0.512	0.235	0.732	0.742	0.797	0.761	0.589	0.787
SO_4														1.00	0.593	0.575	0.672	0.759	0.841	0.734	-0.040
NO_3															1.00	0.101	0.250	0.578	0.733	0.763	-0.141
Ca																1.00	0.986	0.557	0.671	0.490	0.304
Mg																	1.00	0.650	0.775	0.616	0.309
Fe																		1.00	0.926	0.908	0.346
Zn																			1.00	0.950	0.189
Mn																				1.00	0.423
Cd																					1.00

Table 2.33 Linear Correlation Coefficient for Water Quality Parameters in R.S. Colony (Tube Well)

	Temp	Tur	pH	Cond.	DO	TH	Acidity	Alkalinity	Chloride	BOD	COD	TS	TDS	SO_4	NO_3	Ca	Mg	Fe	Zn	Mn	Cd
Temp	1.00	0.952	-0.821	0.785	-0.951	0.834	0.475	0.352	0.760	0.612	0.882	0.902	0.752	0.712	0.775	0.879	0.722	0.826	0.931	0.948	0.792
Tur		1.00	-0.788	0.816	-0.823	0.788	0.583	0.465	0.723	0.622	0.916	0.854	0.724	0.823	0.895	0.848	0.658	0.752	0.891	0.880	0.672
pH			1.00	-0.568	0.804	-0.726	-0.164	0.174	-0.865	-0.136	-0.776	-0.642	-0.248	-0.782	-0.712	-0.798	-0.577	-0.515	-0.786	-0.723	-0.479
Cond.				1.00	-0.723	0.871	0.065	0.097	0.946	0.231	0.952	0.828	0.363	0.787	0.890	0.913	0.762	0.557	0.914	0.779	0.597
DO					1.00	-0.805	-0.315	-0.253	-0.744	-0.594	-0.798	-0.893	-0.718	-0.595	-0.593	-0.829	-0.728	-0.876	-0.908	-0.943	-0.864
TH						1.00	-0.0003	0.200	0.821	0.267	0.932	0.944	0.595	0.534	0.820	0.987	0.969	0.518	0.956	0.910	0.831
Acidity							1.00	0.658	-0.046	0.773	0.233	0.206	0.589	0.470	0.320	0.079	-0.122	0.556	0.193	0.307	0.139
Alkalinity								1.00	-0.179	0.846	0.343	0.437	0.810	0.058	0.321	0.160	0.251	0.489	0.297	0.443	0.480
Chloride									1.00	0.067	0.848	0.734	0.207	0.772	0.766	0.881	0.689	0.509	0.856	0.710	0.519
BOD										1.00	0.431	0.558	0.864	0.242	0.300	0.272	0.246	0.847	0.469	0.621	0.613
COD											1.00	0.936	0.614	0.736	0.932	0.955	0.849	0.644	0.971	0.903	0.749
TS												1.00	0.781	0.504	0.772	0.929	0.920	0.740	0.978	0.986	0.934
TDS													1.00	0.220	0.485	0.562	0.614	0.742	0.670	0.827	0.844
SO_4														1.00	0.838	0.998	0.529	0.636	0.844	0.596	0.361
NO_3															1.00	0.869	0.705	0.433	0.833	0.735	0.507
Ca																1.00	0.917	0.601	0.968	0.906	0.776
Mg																	1.00	0.438	0.888	0.870	0.873
Fe																		1.00	0.731	0.925	0.738
Zn																			1.00	0.966	0.855
Mn																				1.00	0.937
Cd																					1.00

Table 2.34 Linear Correlation Coefficient for Water Quality Parameters in Bortolli (Tube Well)

	Temp	Tur	pH	Cond.	DO	TH	Acidity	Alkalinity	Chloride	BOD	COD	TS	TDS	SO_4	NO_3	Ca	Mg	Fe	Zn	Mn	Cd
Temp	1.00	0.903	0.187	0.626	-0.890	0.640	0.452	0.788	0.858	0.964	0.807	0.530	0.745	0.478	0.866	0.682	0.521	0 .968	0.667	0.917	0.912
Tur		1.00	-0.015	0.519	-0.819	0.686	0.682	0.831	0.802	0.952	0.879	0.404	0.731	0.480	0.833	0.684	0. 617	0 .825	0.749	0.899	0.746
pH			1.00	-0.231	0.243	0.579	0.164	-0.260	0.246	0.260	0.278	0.201	-0.019	-0.509	-0.260	0.550	0.600	0 .389	0.070	-0.118	0.173
Cond.				1.00	-0.735	0.157	-0.064	0.437	0.807	0.512	0.745	0.943	0.903	0.552	0.853	0.282	-0.032	0.543	0.701	0.793	0.798
DO					1.00	-0.294	-0.261	-0.879	-0.948	-0.782	-0.859	-0.627	-0.696	-0.732	-0.956	-0.368	-0.149	-0.774	-0.530	-0.934	-0.829
TH						1.00	0.839	0.437	0.228	0.788	0.337	-0.001	0.482	0.115	0.304	0.983	0.878	0.669	0.558	0.549	0.442
Acidity							1.00	0.597	0.127	0.632	0.300	-0.282	0.235	0.310	0.216	0.783	0.863	0.379	0.340	0.478	0.116
Alkalinity								1.00	0.719	-0.487	0.682	0.224	0.454	0.749	0.759	0.482	0.345	0.628	0.324	0.866	0.543
Chloride									1.00	0.760	0.947	0.785	0.802	0.542	0.986	0.285	0.091	0.777	0.682	0.882	0.899
BOD										1.00	0.787	0.408	0.733	0.373	0.783	0.797	0.705	0.944	0.734	0.875	0.833
COD											1.00	0.728	0.847	0.449	0.951	0.347	0.237	0.722	0.831	0.861	0.825
TS												1.00	0.857	0.293	0.787	0.096	-0.166	0.501	0.716	0.618	0.796
TDS													1.00	0.369	0.855	0.552	0.336	0.701	0.930	0.830	0.858
SO_4														1.00	0.622	0.232	-0.022	0.262	0.099	0.725	0.322
NO_3															1.00	0.373	0.156	0.765	0.729	0.937	0.887
Ca																1.00	0.926	0.693	0.327	0.625	0.503
Mg																	1.00	0.565	0.477	0.402	0.092
Fe																		1.00	0.666	0.801	0.920
Zn																			1.00	0.691	0.763
Mn																				1.00	0.831
Cd																					1.00

Table 2.35 Linear Correlation Coefficient for Water Quality Parameters in Diesel Colony (Treated)

	Temp	Tur	pH	Cond.	DO	TH	Acidity	Alkalinity	Chloride	BOD	COD	TS	TDS	SO_4	NO_3	Ca	Mg	Fe	Zn	Mn	Cd
Temp	1.00	0.119	0.882	0.549	0.552	0.606	0.248	0.729	0.948	0.981	0.912	-0.125	0.112	0.961	0.785	0.343	0.787	0.210	0.682	0.444	0.058
Tur		1.00	0.391	0.659	0.330	0.287	-0.127	-0.388	0.623	0.027	0.010	0.916	0.929	0.160	-0.456	0.147	0.371	0.949	0.565	0.941	0.969
pH			1.00	0.706	-0.820	0.796	0.188	0.644	0.955	0.874	0.875	0.094	0.295	0.889	0.570	0.598	0.931	0.478	0.753	0.664	0.324
Cond.				1.00	-0.854	0.336	0.122	0.224	0.760	0.417	0.598	0.362	0.470	0.508	0.183	-0.087	0.723	0.538	0.406	0.407	0.744
DO					1.00	-0.344	-0.235	-0.587	-0.294	-0.132	-0.154	-0.043	-0.260	-0.769	-0.620	-0.654	-0.758	-0.255	-0.520	-0.586	-0.382
TH						1.00	0.078	0.538	0.629	0.621	0.653	0.021	0.165	0.561	0.354	0.768	0.848	0.444	0.672	0.462	0.145
Acidity							1.00	0.298	0.240	0.259	0.276	-0.312	-0.147	0.222	0.304	-0.017	0.168	-0.127	0.033	-0.028	-0.106
Alkalinity								1.00	0.719	0.789	0.891	0.691	0.507	0.622	0.911	0.181	0.664	-0.337	0.166	0.098	-0.376
Chloride									1.00	0.895	0.945	-0.023	0.213	0.883	0.706	0.300	0.901	0.305	0.669	0.584	0.270
BOD										1.00	0.895	-0.244	-0.018	0.958	0.837	0.433	0.735	0.100	0.628	0.307	0.100
COD											1.00	-0.317	-0.070	0.795	0.856	0.384	0.883	0.034	0.529	0.326	0.002
TS												1.00	-0.116	-0.015	-0.670	-0.067	0.037	0.894	0.443	0.783	0.866
TDS													1.00	0.171	0.426	0.021	0.254	0.895	0.672	0.876	0.854
SO_4														1.00	0.675	0.313	0.687	0.296	0.671	0.470	0.091
NO_3															1.00	0.154	0.533	-0.417	0.275	-0.142	-0.466
Ca																1.00	0.486	0.368	0.501	0.257	-0.067
Mg																	1.00	0.422	0.691	0.630	0.350
Fe																		1.00	0.655	0.923	0.861
Zn																			1.00	0.739	0.398
Mn																				1.00	0.896
Cd																					1.00

Table 2.36 Linear Correlation Coefficient for Water Quality Parameters in Diesel Colony (Tube Well)

	Temp	Tur	pH	Cond.	DO	TH	Acidity	Alkalinity	Chloride	BOD	COD	TS	TDS	SO_4	NO_3	Ca	Mg	Fe	Zn	Mn	Cd
Temp	1.00	0.975	0.584	0.558	-0.961	0.985	0.567	0.607	0.784	0.729	0.733	0.889	0.881	0.965	0.880	0.879	0.708	0.790	0.492	0.337	0.811
Tur		1.00	0.573	0.425	-0.926	0.988	0.647	0.660	0.696	0.846	0.789	0.870	0.765	0.902	0.771	0.843	0.770	0.747	0.343	0.190	0.777
pH			1.00	0.666	-0.607	0.591	-0.130	0.792	0.078	0.549	0.267	0.154	0.359	0.448	0.354	0.366	0.671	0.164	0.440	0.476	0.937
Cond.				1.00	0.561	0.471	0.055	0.380	0.511	0.243	0.227	0.296	0.628	0.626	0.676	0.535	0.162	0.387	0.645	0.646	0.722
DO					1.00	-0.971	-0.407	-0.397	-0.781	-0.644	-0.535	-0.818	-0.880	-0.945	-0.821	-0.935	-0.596	-0.870	-0.666	-0.531	-0.782
TH						1.00	0.558	0.556	0.731	0.792	0.696	0.861	0.819	0.929	0.795	0.281	0.724	0.805	0.476	0.327	0.792
Acidity							1.00	0.766	0.585	0.683	0.889	0.792	0.392	0.556	0.503	0.501	0.398	0.490	-0.310	-0.494	0.122
Alkalinity								1.00	0.393	0.795	0.933	0.581	0.347	0.540	0.530	0.380	0.576	0.223	-0.269	-0.368	0.513
Chloride									1.00	0.353	0.530	0.891	0.955	0.913	0.909	0.895	0.159	0.915	0.547	0.369	0.372
BOD										1.00	0.804	0.595	0.336	0.593	0.246	0.589	0.723	0.440	-0.077	-0.166	0.632
COD											1.00	0.785	0.939	0.661	0.637	0.496	0.690	0.394	-0.202	-0.363	0.498
TS												1.00	0.858	0.914	0.874	0.834	0.520	0.832	0.302	0.004	0.470
TDS													1.00	0.952	0.970	0.852	0.404	0.835	0.706	0.544	0.634
SO_4														1.00	0.950	0.934	0.509	0.877	0.585	0.421	0.706
NO_3															1.00	0.806	0.425	0.760	0.563	0.398	0.641
Ca																1.00	0.330	0.970	0.630	0.488	0.572
Mg																	1.00	0.201	0.030	0.060	0.773
Fe																		1.00	0.633	0.476	0.393
Zn																			1.00	0.975	0.507
Mn																				1.00	0.466
Cd																					1.00

Table 2.37 Calculated and Experimental value of Total Dissolved Solids and Cadmium as a function of Total Solids and Manganese respectively. (Sector – A Treated)

Total Solid in mg/l	Total Dissolved Solids in mg/l		% of error	Manganese in mg/l	Cadmium in mg/l		% of error
	Calculated	Experimental			Calculated	Experimental	
161.5	130.23	127.5	2.11	0.054	0.0053	0.005	6.2
218.25	184.17	184.5	0.17	0.086	0.0065	0.0069	4.9
148.0	117.4	116.0	1.19	0.023	0.0041	0.0045	8.2
201.75	168.49	167.25	0.73	0.068	0.0058	0.0057	2.9
215.0	181.08	182.75	0.91	0.097	0.0069	0.0071	1.52
139.5	109.32	112.75	3.09	0.034	0.0045	0.0043	5.9

Table 2.38 Calculated and Experimental value of pH and Manganese as a function of Temperature and Calcium respectively. (Sector – C, Treated)

Temperature in ^{0}C	pH		% of error	Calcium in mg/l	Manganese in mg/l		% of error
	Calculated	Experimental			Calculated	Experimental	
31.52	7.64	7.6	0.52	72.82	0.063	0.063	0
23.22	7.46	7.3	2.16	80.5	0.098	0.105	6.9
18.65	7.36	7.46	1.34	67.2	0.038	0.036	5.4
31.23	7.63	7.62	0.13	79.58	0.094	0.087	7.74
24.57	7.49	7.54	0.66	86.37	0.124	0.125	0.8
17.22	7.32	7.37	0.68	67.47	0.039	0.043	9.7

Table 2.39 Calculated and Experimental value of D.O and Acidity as a function of Temperature and pH respectively. (Sector – E, Treated)

Temperature in ^{0}C	D.O		% of error	pH	Acidity in mg/l		% of error
	Calculated	Experimental			Calculated	Experimental	
31.05	6.71	6.82	1.62	7.56	15.29	15.25	0.003
23.47	6.94	7.0	0.86	7.37	6.78	5.75	16.55
16.42	7.15	7.15	0	7.45	10.47	9.25	11.67
32.12	6.67	6.55	1.81	7.72	22.31	20.75	7.0
23.75	6.93	6.93	0	7.35	6.08	6.75	9.8
16.37	7.15	7.13	0.28	7.52	13.54	16.0	15.36

Table 2.40 Calculated and Experimental value of B.O.D and Calcium as a function of D.O. and Total Hardness respectively. (Sector – B, Tube Well)

D.O.in mg/l	B.O.D. mg/l		% of error	Total hardness in mg/l	Calcium I mg/l		% of error
	Calculated	Experimental			Calculated	Experimental	
6.96	1.18	1.32	10.1	151.0	102.94	102.5	0.428
7.09	0.858	7.25	15.5	168.25	113.26	113.92	0.58
7.17	0.656	0.55	15.41	142.0	97.56	96.3	1.29
6.82	1.53	1.47	4.67	164.5	111.02	113.54	2.24
7.15	0.71	0.83	14.4	189.75	126.12	124.85	1.01
7.09	0.858	0.91	5.68	141.25	97.11	97.37	0.26

Table 2.41 Calculated and Experimental Value of Total Solids and D.O. as a Function of Total Dissolved Solids and Sulphate Respectively. (Sector – D, Tube Well)

Total Solids in mg/l	Total Dissolved Solids in mg./l		% of error	D.O. in mg/l	Sulphate in mg/l		% of error
	Calculated	Experimental			Calculated	Experimental	
330.0	283.085	288.25	1.8	6.72	15.711	16.47	4.71
278.0	238.833	232.5	2.68	7.12	12.177	11.65	4.42
254.25	218.62	217.0	0.743	7.1	12.354	12.3	0.43
285.25	245.0	242.0	1.23	6.69	15.976	16.2	1.39
248.0	213.303	214.5	0.55	6.85	14.563	14.7	0.93
224.0	192.879	197.5	2.36	7.11	12.266	12.6	2.68

Table 2.42 Calculated and Experimental value of Temperature and Manganese as a function of Dissolved Oxygen (D.O) and Cadmium respectively. (Tilkanagar, Tube Well)

Temperature in ^{0}C	D.O. in mg/l		% of error	Manganese in mg/l	Cadmium in mg/l		% of error
	Calculated	Experimental			Calculated	Experimental	
29.9	6.612	6.5	1.7	0.334	0.00903	0.0087	3.7
25.1	6.972	7.0	0.4	0.216	0.0077	0.0075	2.63
23.72	7.076	7.12	0.61	0.103	0.0064	0.0064	0
30.2	6.59	6.64	0.75	0.326	0.0089	0.0092	3.3
25.6	6.935	7.02	1.21	0.258	0.0081	0.0085	4.82
22.08	7.19	7.1	1.25	0.157	0.007	0.0071	1.41

Table 2.43 Rating for Water Quality Index

Sampling Stations	Source	Year	Season	WQI	Interferences
1 Sector - A	Treated	94-95	Summer	51.420	Poor
			Rainy	67.076	Poor
			Winter	45.136	Good
		95-96	Summer	56.390	Poor
			Rainy	70.426	Poor
			Winter	43.128	Good
2 Sector - C	Treated	94-95	Summer	66.346	Poor
			Rainy	54.810	Poor
			Winter	37.698	Good
		95-96	Summer	64.370	Poor
			Rainy	59.758	Poor
			Winter	46.584	Good
3 Sector - E	Treated	94-95	Summer	38.781	Good
			Rainy	58.973	Poor
			Winter	27.642	Good
		95-96	Summer	39.057	Good
			Rainy	62.829	Poor
			Winter	29.665	Good
4 Sector - B	Tube Well	94-95	Summer	68.388	Poor
			Rainy	59.207	Poor
			Winter	52.008	Poor
		95-96	Summer	63.274	Poor
			Rainy	71.964	Poor
			Winter	64.631	Poor
5 Sector - D	Tube Well	94-95	Summer	79.874	Very poor
			Rainy	64.455	Poor
			Winter	54.88	Poor
		95-96	Summer	88.218	Very poor
			Rainy	78.286	Very poor
			Winter	65.966	Poor
6 Tilkanagar	Tube Well	94-95	Summer	91.286	Very poor
			Rainy	78.314	Very poor
			Winter	66.867	Poor
		95-96	Summer	107.477	Unfit for drinking
			Rainy	88.225	Very poor
			Winter	74.99	Poor

Sampling Stations	Source	Year	Season	WQI	Interferences
7 Tilkanagar	Open Well	94-95	Summer	34.08	Good
			Rainy	39.324	Good
			Winter	22.321	Excellent
		95-96	Summer	48.594	Good
			Rainy	35.737	Good
			Winter	25.389	Excellent
8 Dumerta	Tube Well	94-95	Summer	70.456	Poor
			Rainy	61.569	Poor
			Winter	52.01	Poor
		95-96	Summer	65.049	Poor
			Rainy	69.273	Poor
			Winter	45.914	Good
9 Dumerta	Open well	94-95	Summer	40.729	Good
			Rainy	31.329	Good
			Winter	23.211	Excellent
		95-96	Summer	42.998	Good
			Rainy	32.864	Good
			Winter	27.468	Good
10 Gundichapalli	Tube Well	94-95	Summer	69.301	Poor
			Rainy	74.469	Poor
			Winter	59.1	Poor
		95-96	Summer	65.9	Poor
			Rainy	75.879	Very Poor
			Winter	54.401	Poor
11 R.S. Colony	Tube Well	94-95	Summer	57.531	poor
			Rainy	52.311	Poor
			Winter	37.965	Good
		95-96	Summer	62.115	poor
			Rainy	55.327	poor
			Winter	45.242	Good
12 Bortoli	Tube Well	94-95	Summer	88.134	Very poor
			Rainy	80.220	Very poor
			Winter	66.781	Poor
		95-96	Summer	86.643	Very poor
			Rainy	77.472	Very poor
			Winter	63.981	Poor

Sampling Stations	Source	Year	Season	WQI	Interferences
13 Diesel Colony	Treated	94-95	Summer	30.604	Good
			Rainy	39.936	Good
			Winter	24.892	Excellent
		95-96	Summer	31.827	Good
			Rainy	47.28	Good
			Winter	26.849	Good
14 Diesel Colony	Tube Well	94-95	Summer	85.449	Very poor
			Rainy	73.366	poor
			Winter	65.241	Poor
		95-96	Summer	97.679	Very poor
			Rainy	84.705	Very poor
			Winter	73.107	Poor

Table 2.44 Overall WQI of Various Study Areas

WQI Level	Water Quality Rating	WQI Value	Study Areas
0-25	Excellent		Nil
26-50	Good	42.8, 33.56, 33.09 and 34.23	Sector-E (Treated), Diesel Colony (Treated) Dumerta (Open Well) and Tilkanagar (Open Well)
51-75	Poor	55.59, 63.18, 54.92, 71.94, 60.7, 66.5 and 51.74	Sector-A (Treated), Sector-B (Tube well), Sector-C (Treated), Sector-D (Tube well), Dumerta (Tube well), Gundichapalli (Tube Well) and R.S. Colony (Tube well)
76-100	Very poor	84.52, 77.2, and 79.9	Tilkanagar (Tube well), Bortolli (Tube well) and Diesel Colony (Tube well)
>100	Unfit for drinking purposes		Nil

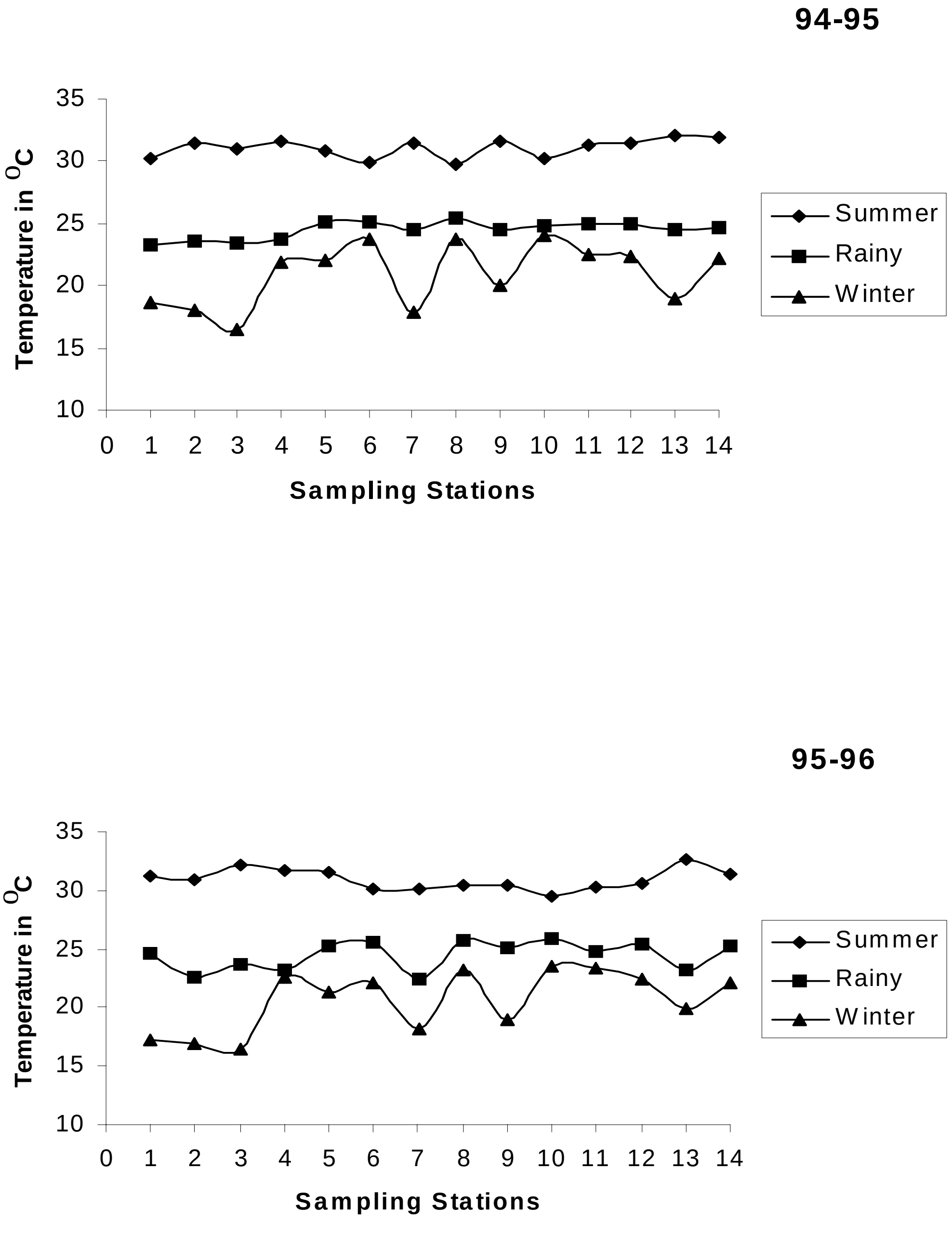


Fig. 2.1 Seasonal Variation in Temperature during 1994-95 and 1995-96

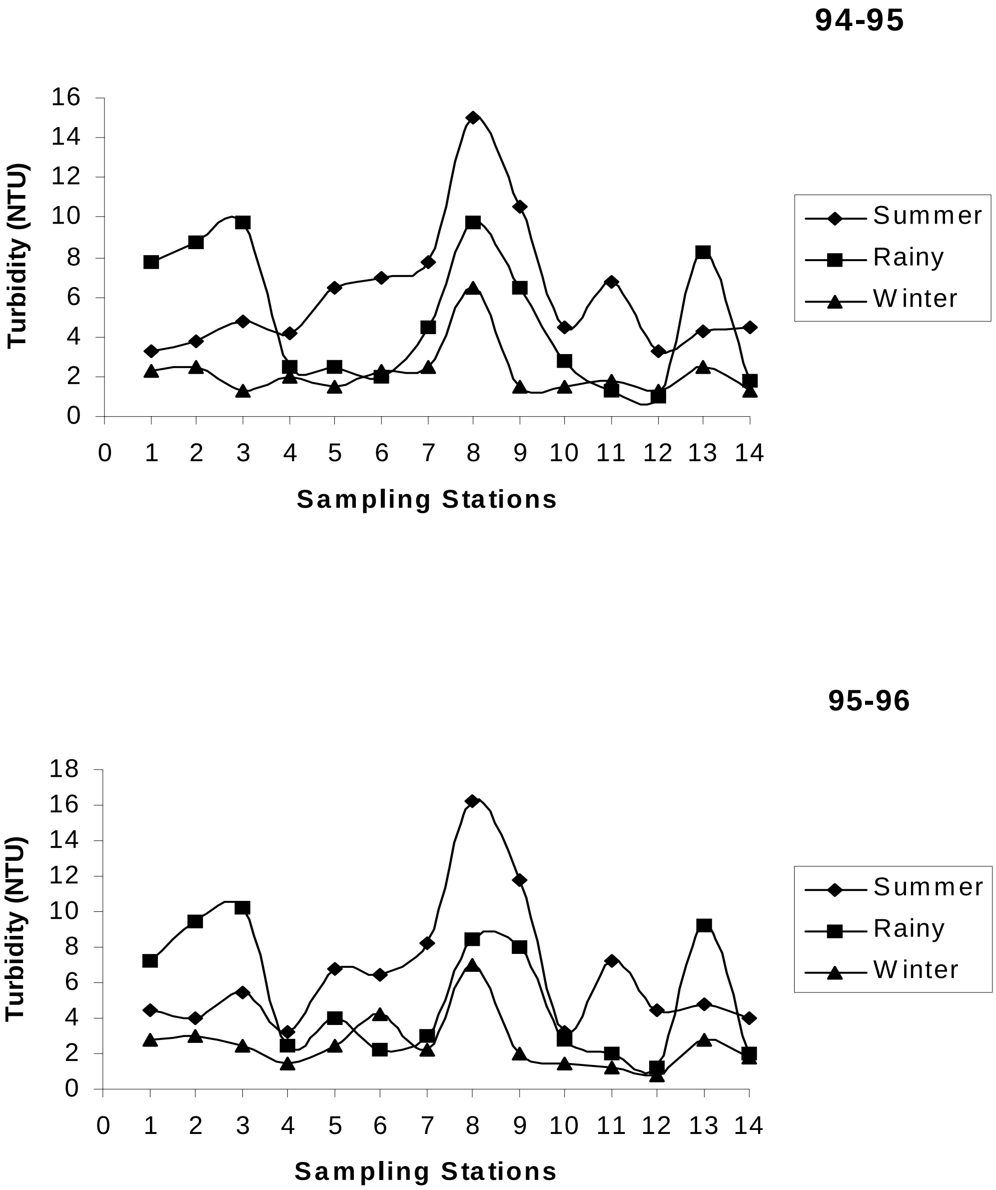
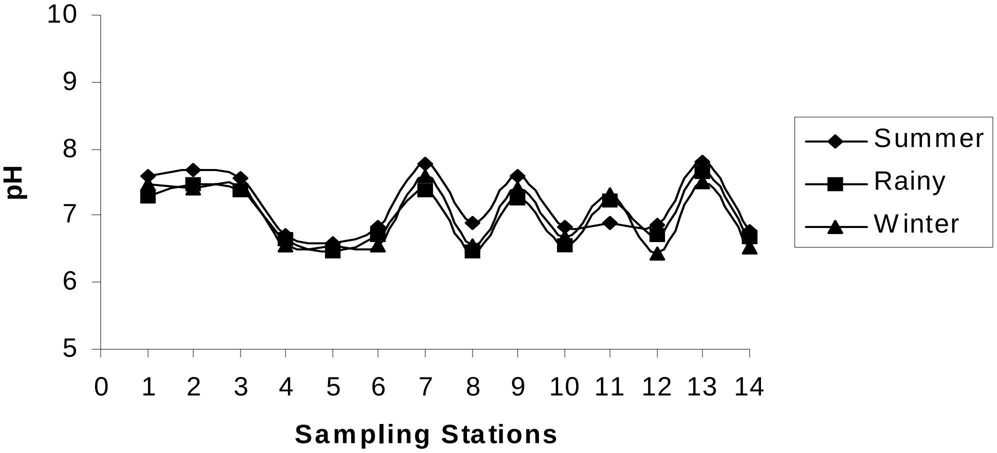


Fig. 2.2 Seasonal Variation in Turbidity during 1994-95 and 1995-96

94-95



95-96

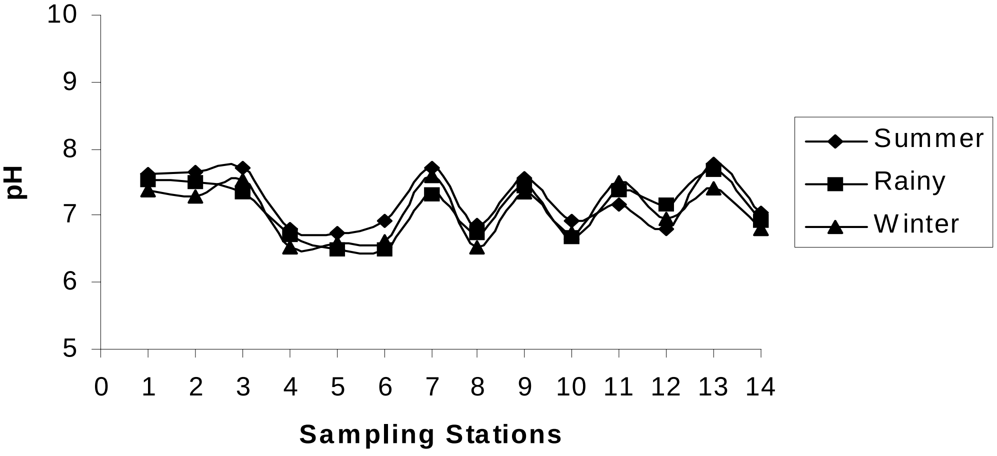


Fig. 2.3 Seasonal Variation in pH during 1994-95 and 1995-96

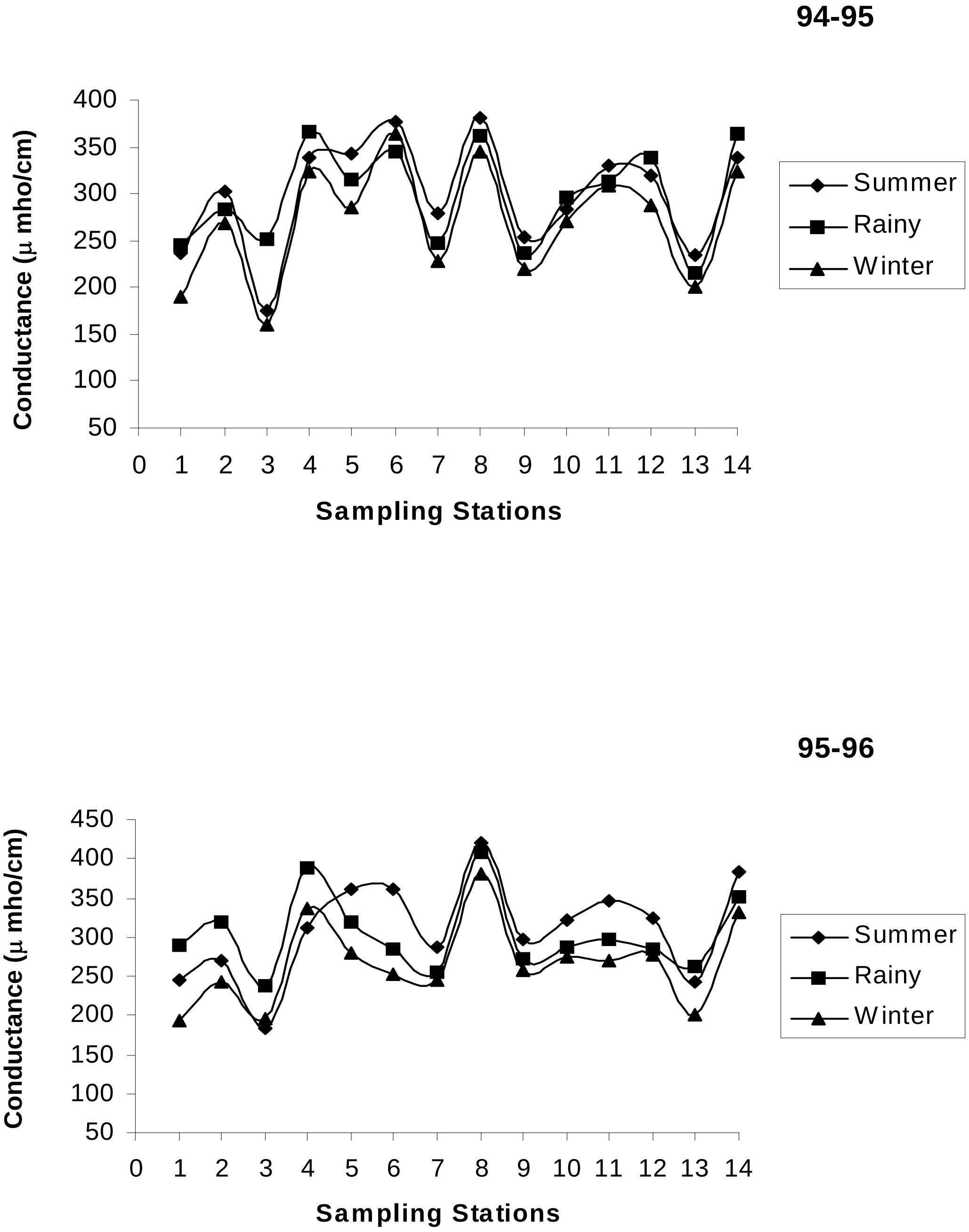


Fig. 2.4 Seasonal Variation in Conductance during 1994-95 and 1995-96

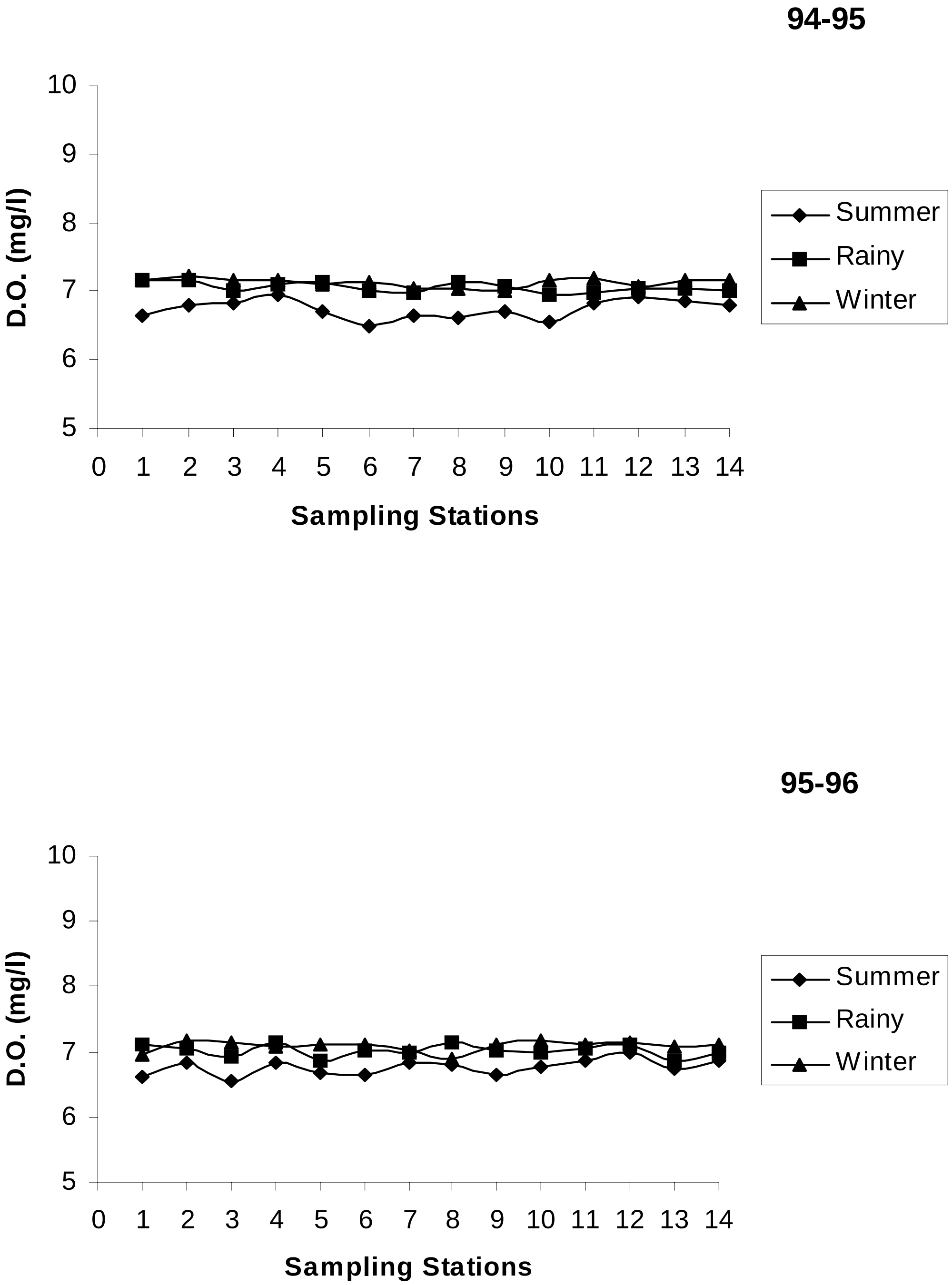


Fig. 2.5 Seasonal Variation in D.O during 1994-95 and 1995-96

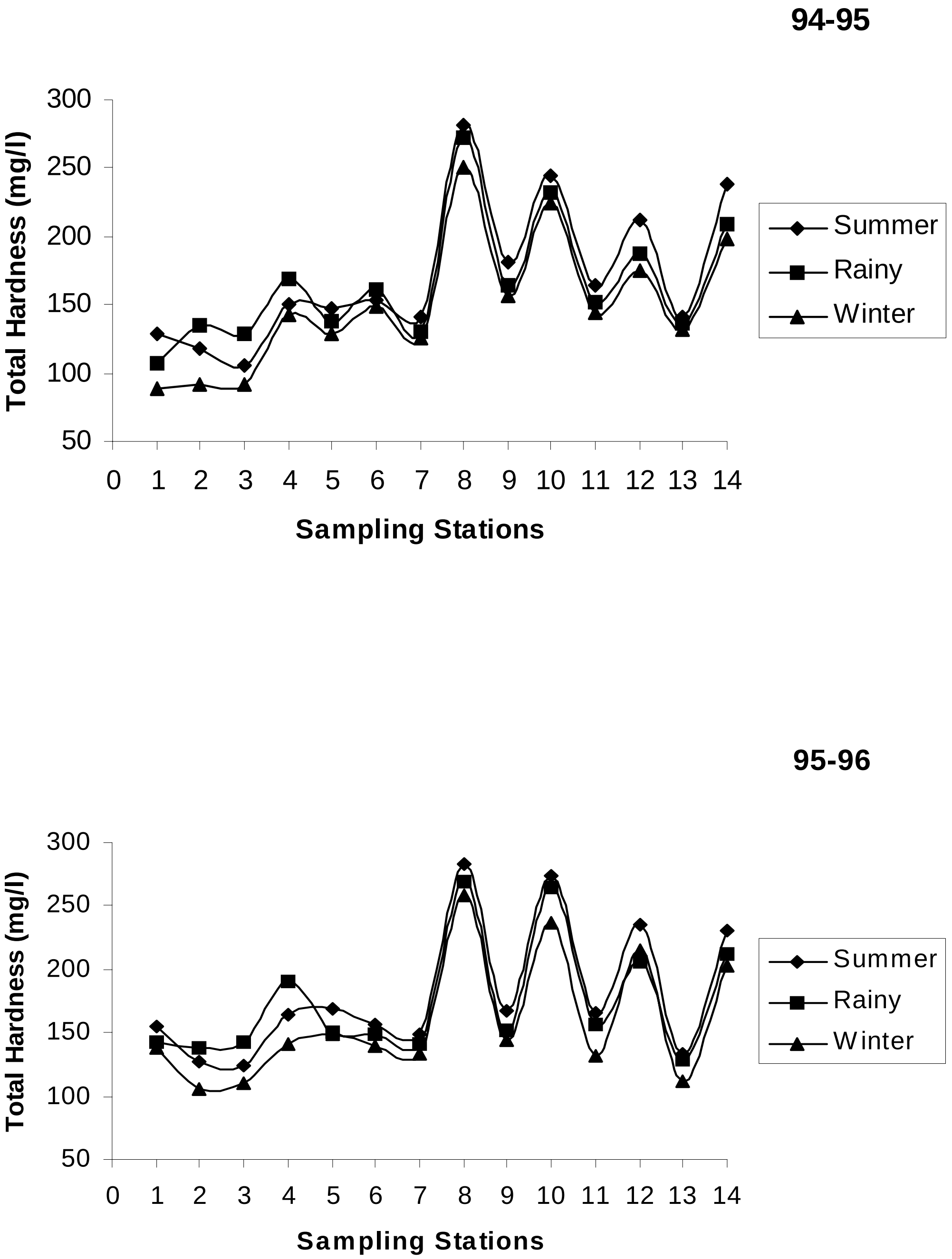
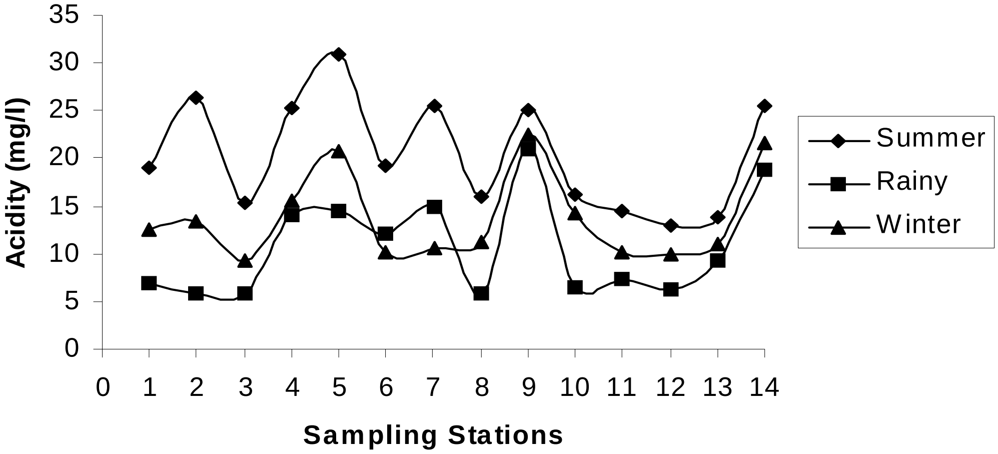


Fig. 2.6 Seasonal Variation in Total Hardness during 1994-95 and 1995-96

94-95



95-96

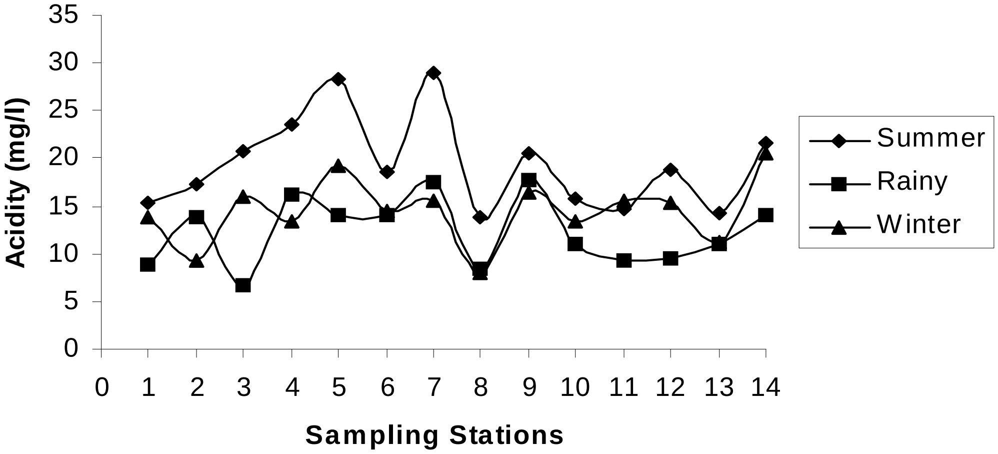
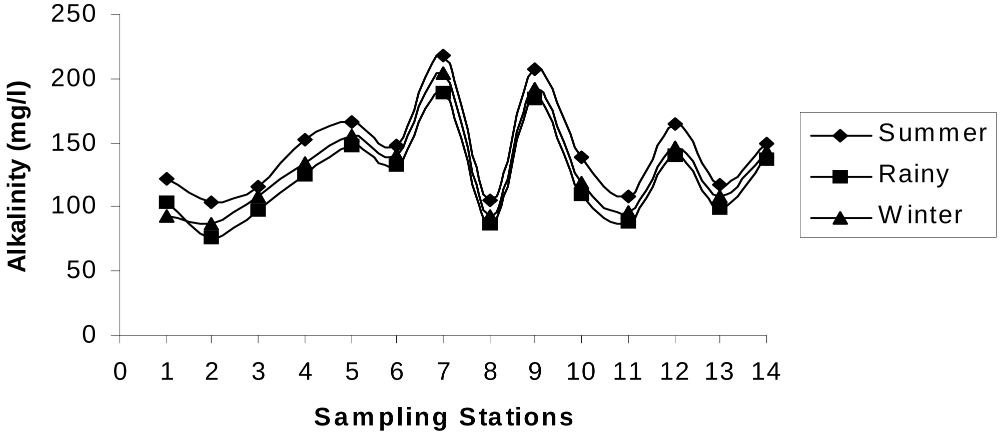


Fig. 2.7 Seasonal Variation in Acidity during 1994-95 and 1995-96

94-95



95-96

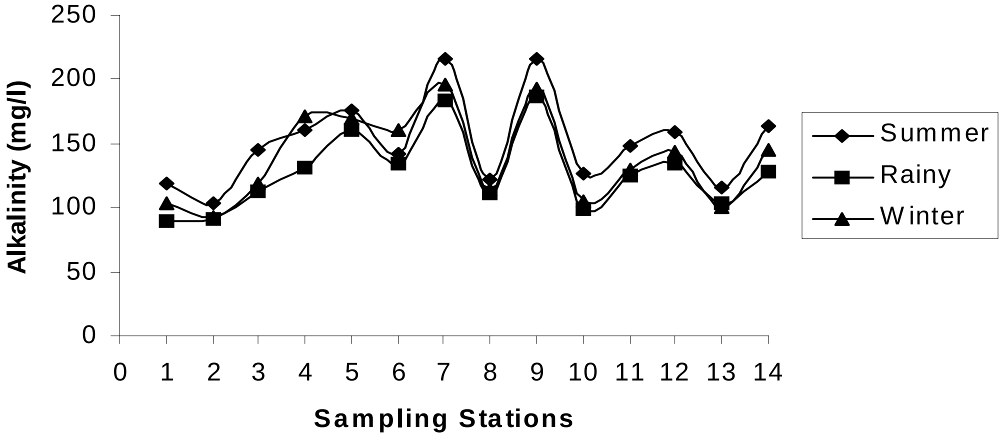
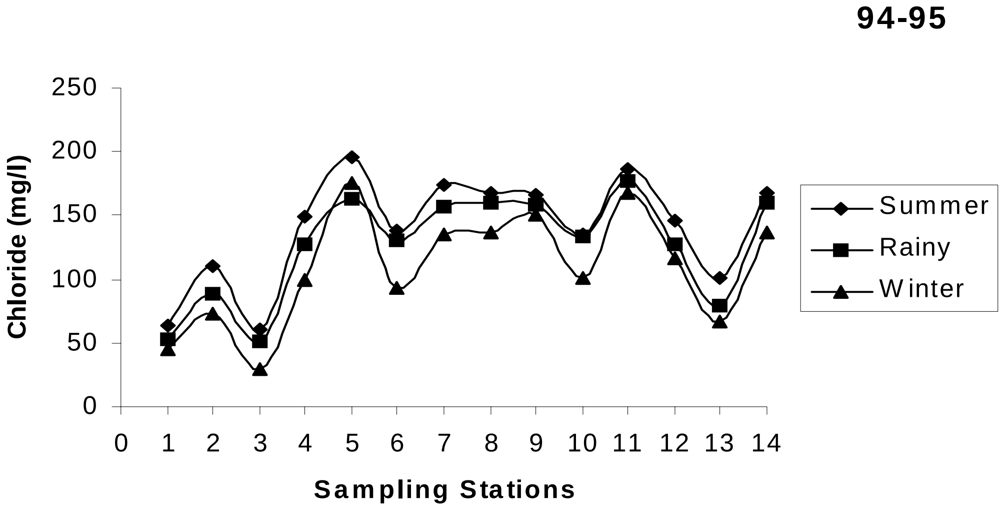


Fig. 2.8 Seasonal Variation in Alkalinity during 1994-95 and 1995-96



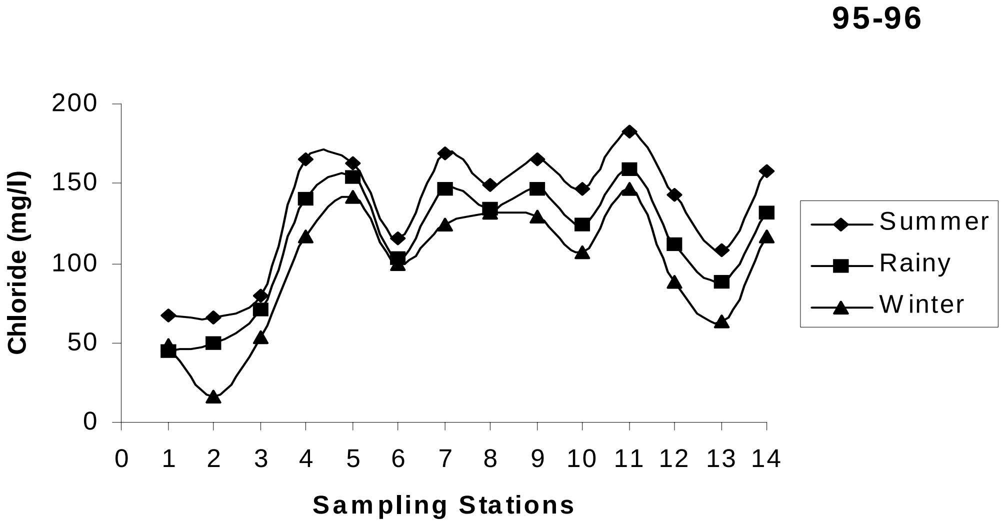
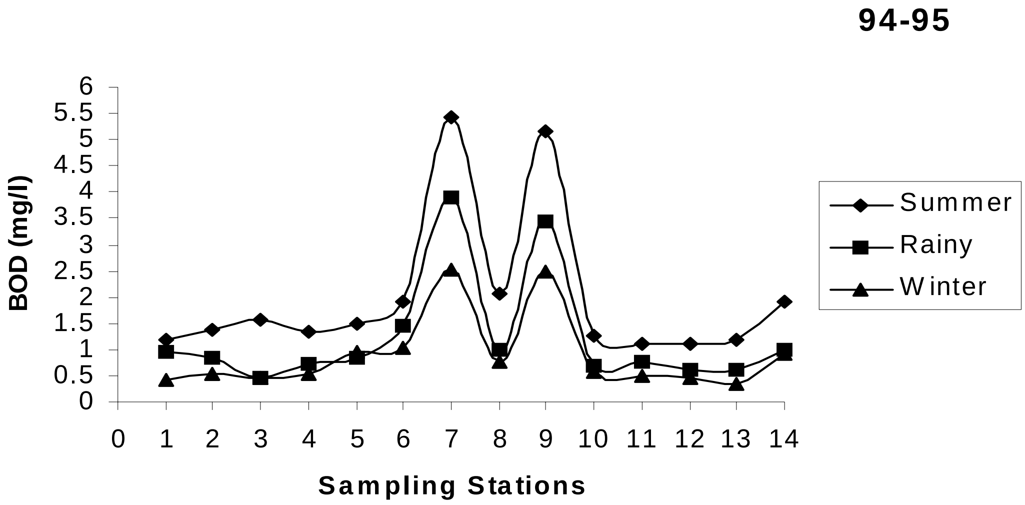


Fig. 2.9 Seasonal Variation in Chloride during 1994-95 and 1995-96



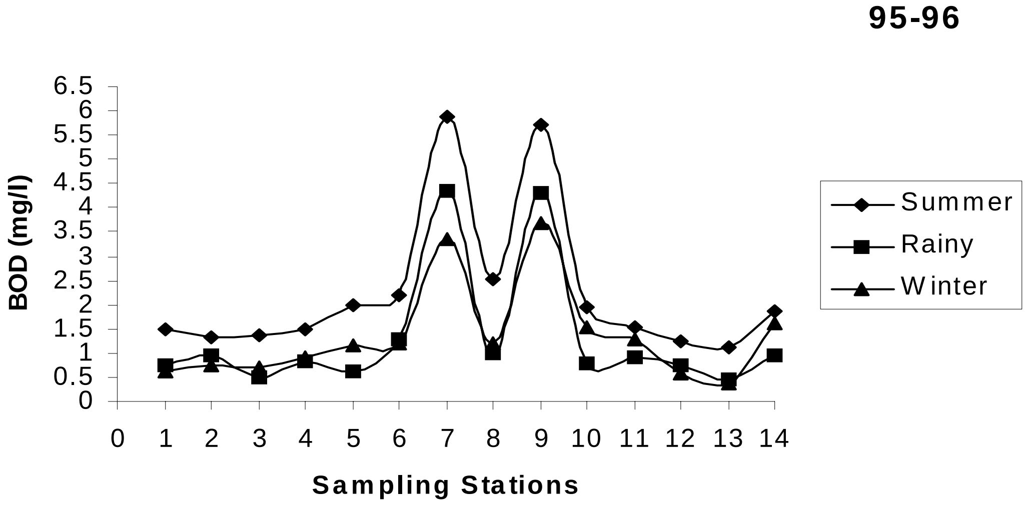
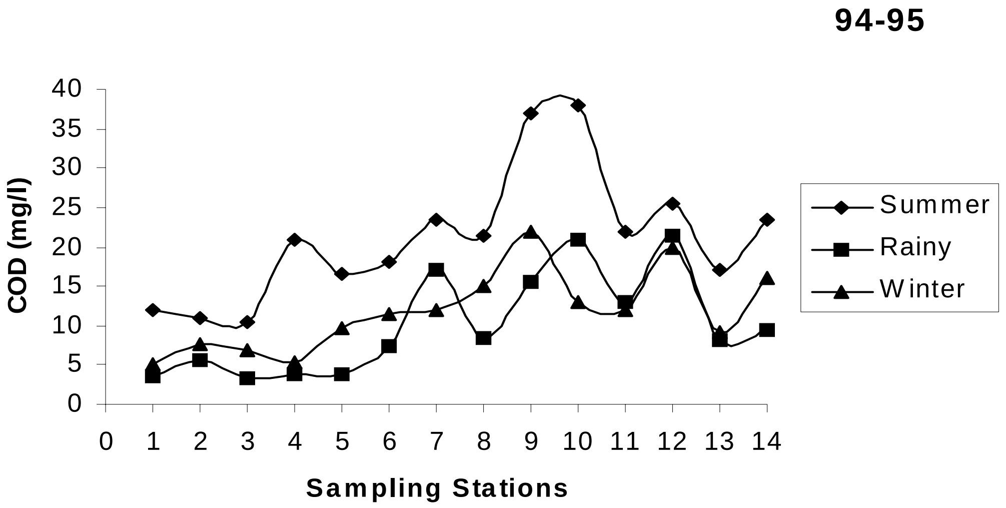


Fig. 2.10 Seasonal Variation in BOD during 1994-95 and 1995-96



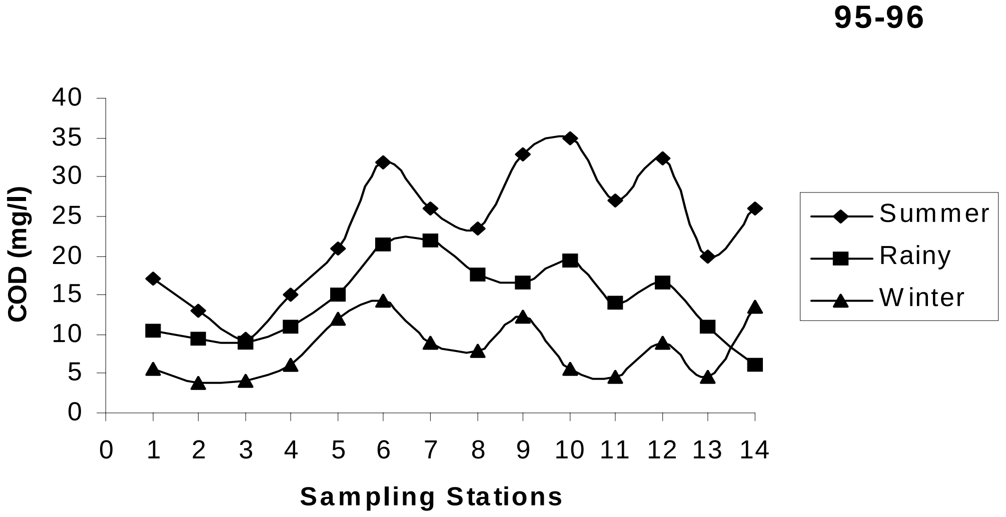


Fig. 2.11 Seasonal Variation in COD during 1994-95 and 1995-96

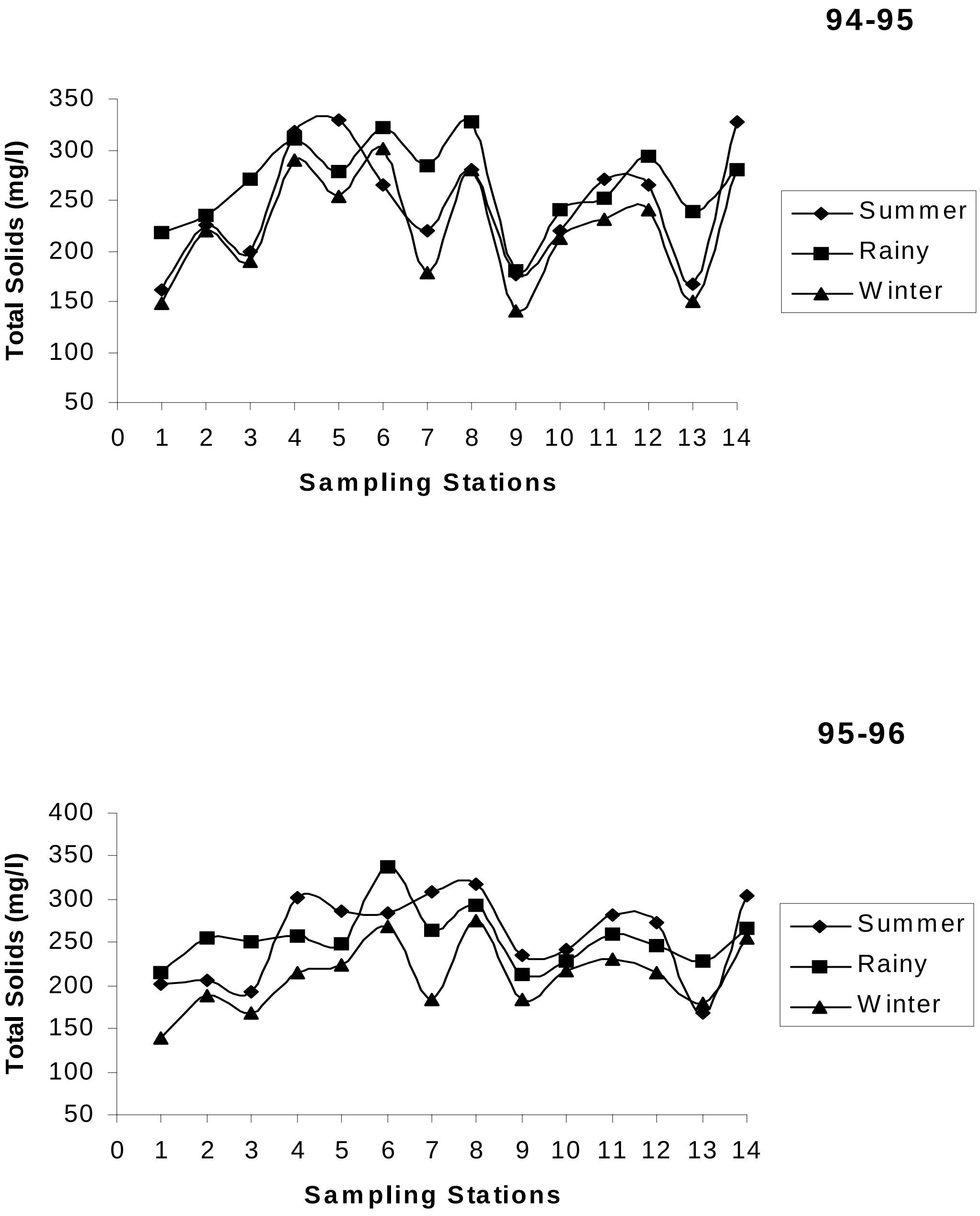


Fig. 2.12 Seasonal Variation in Total Solids during 1994-95 and 1995-96

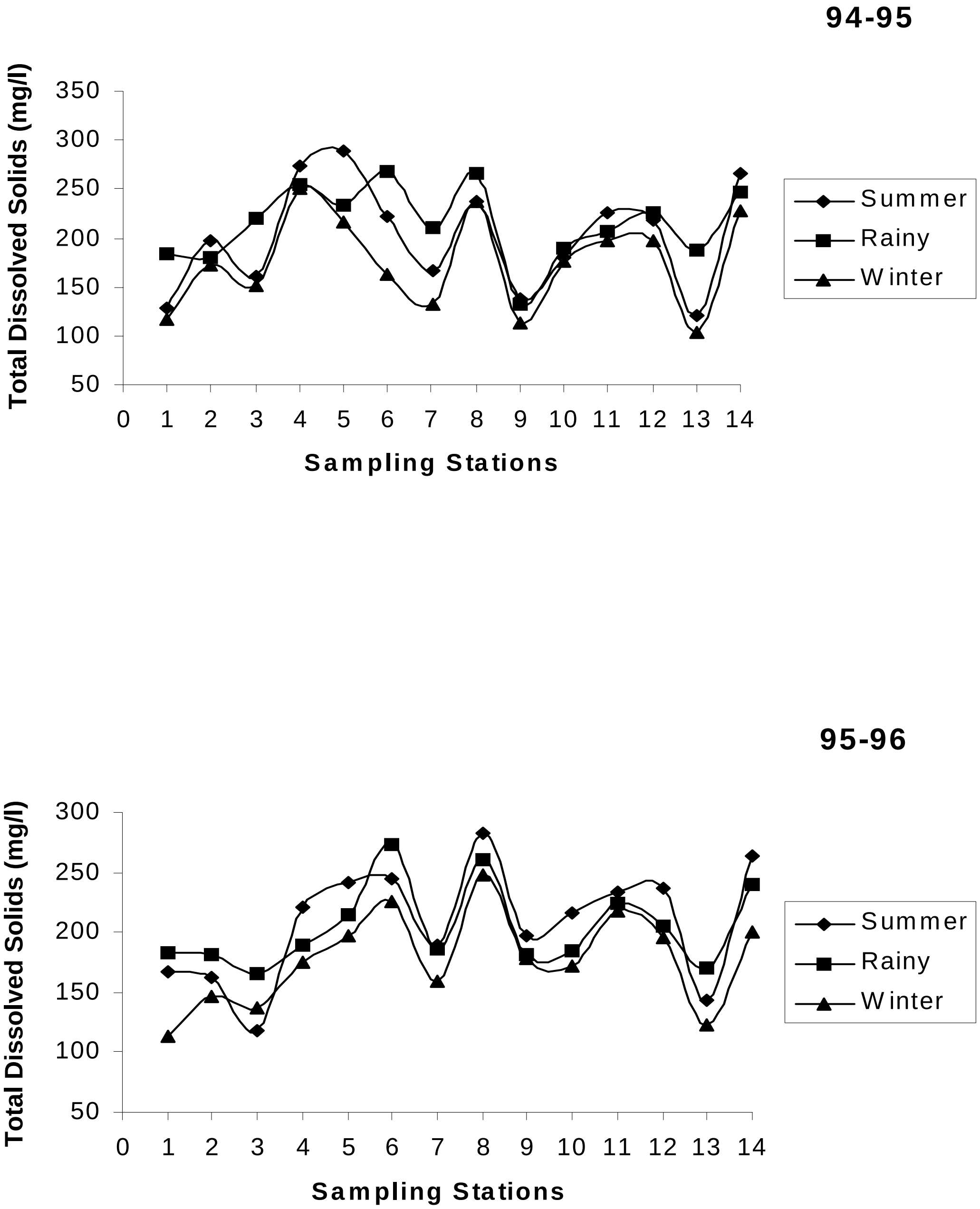
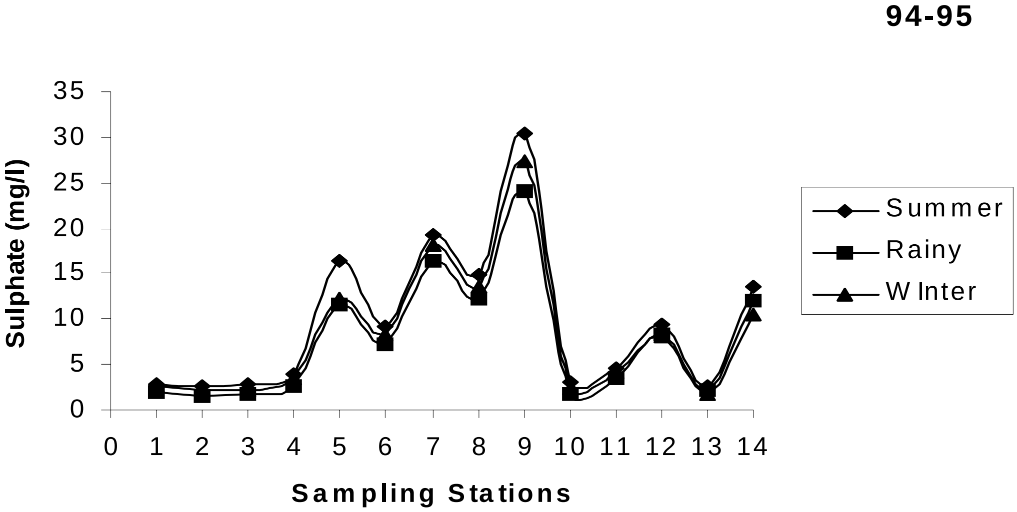


Fig. 2.13 Seasonal Variation in Total Dissolved Solids during 1994-95 and 1995-96



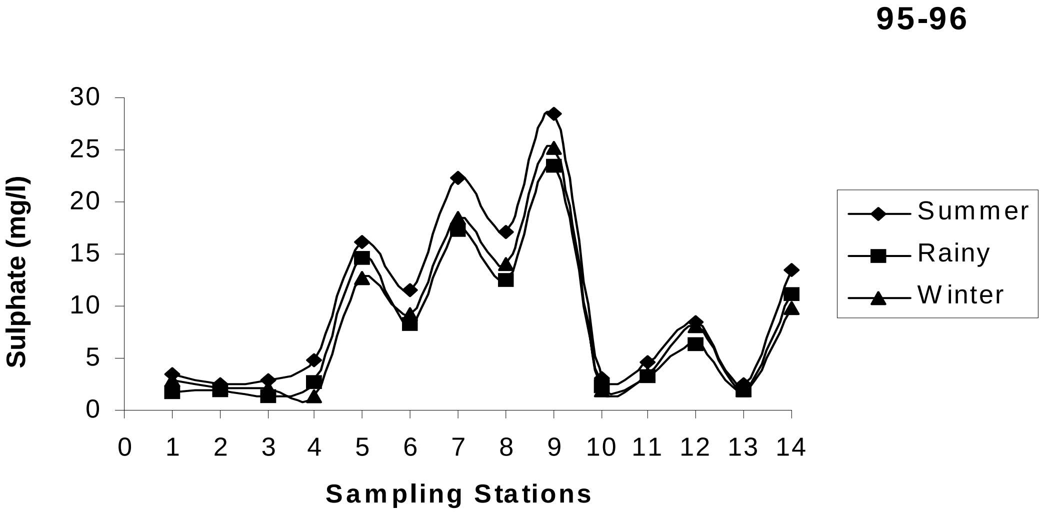
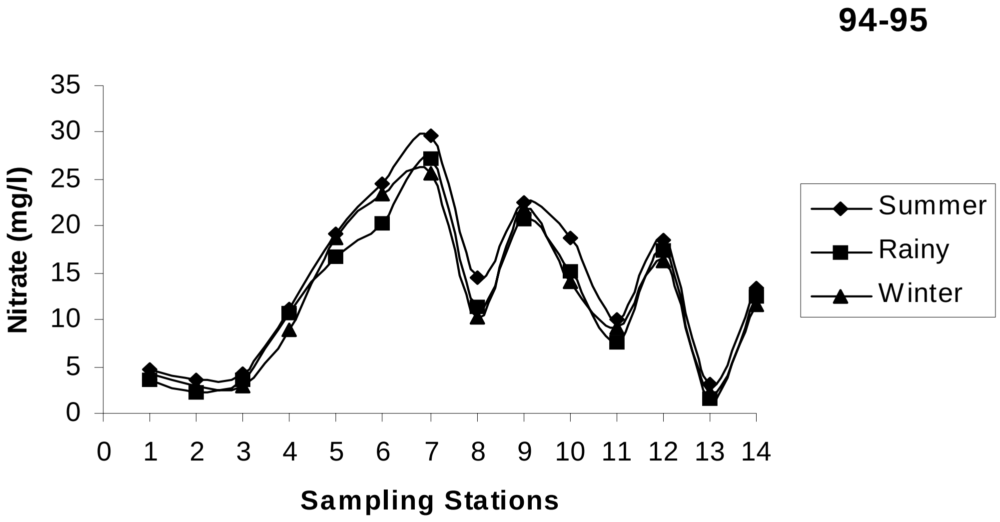
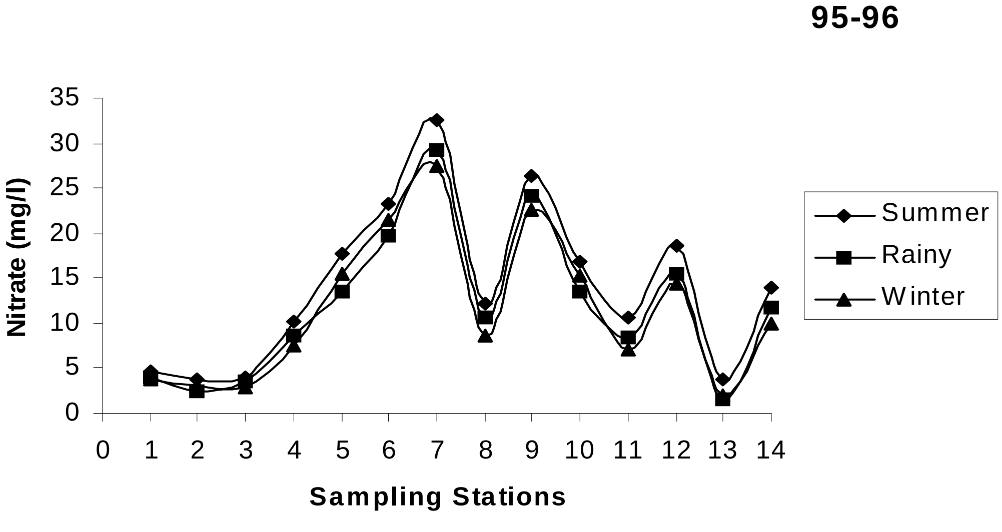


Fig. 2.14 Seasonal Variation in Sulphate during 1994-95 and 1995-96

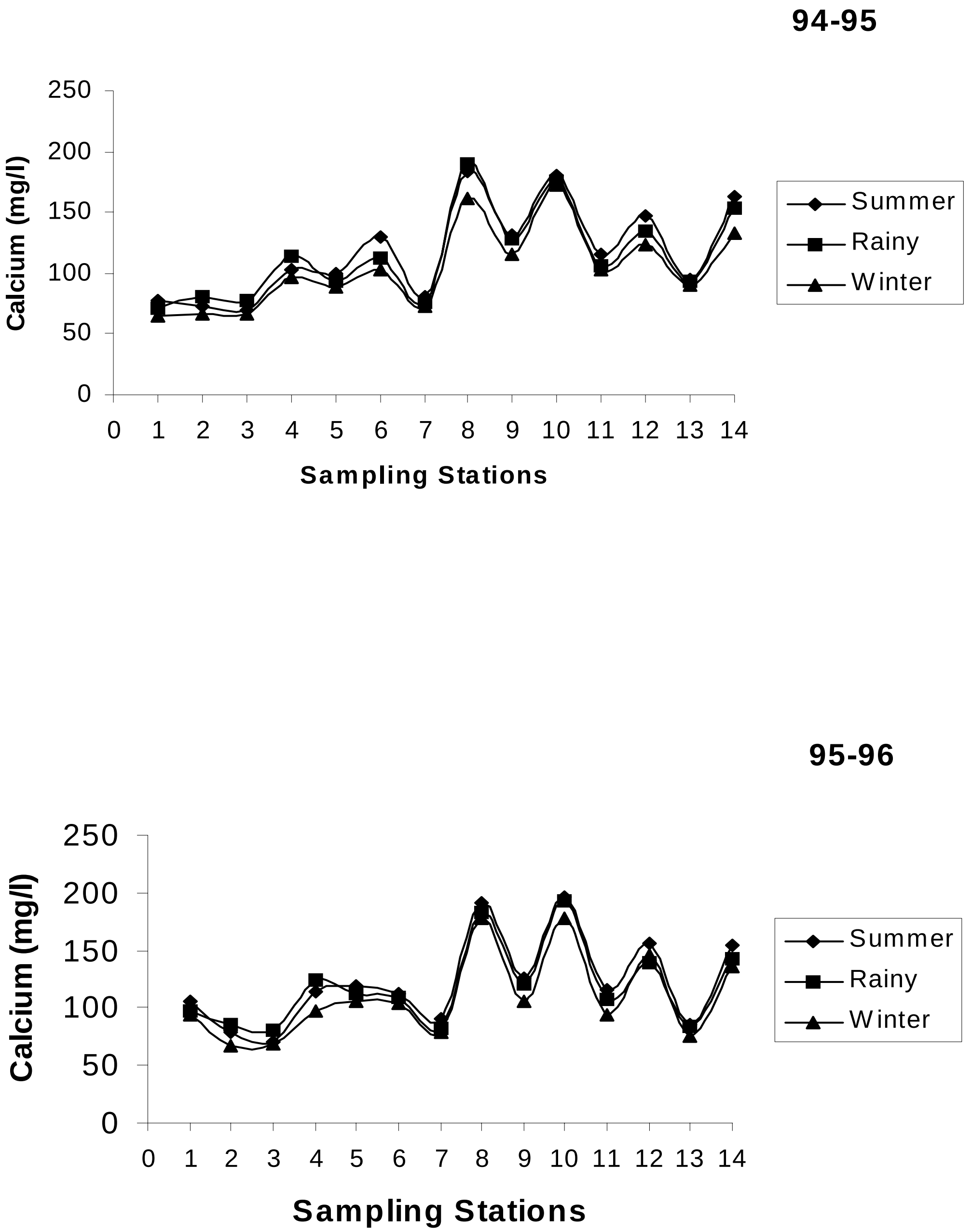


94-95



95-96

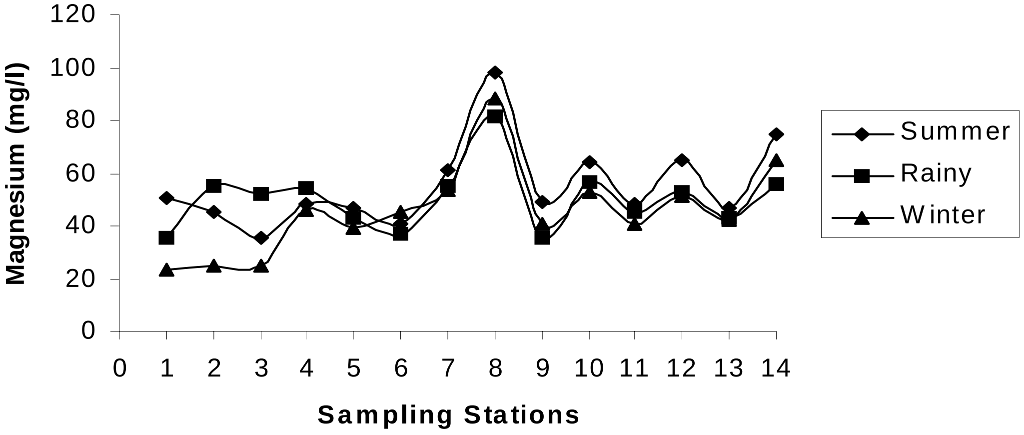
Fig. 2.15 Seasonal Variation in Nitrate during 1994-95 and 1995-96


94-95

95-96

Fig. 2.16 Seasonal Variation in Calcium during 1994-95 and 1995-96

94-95



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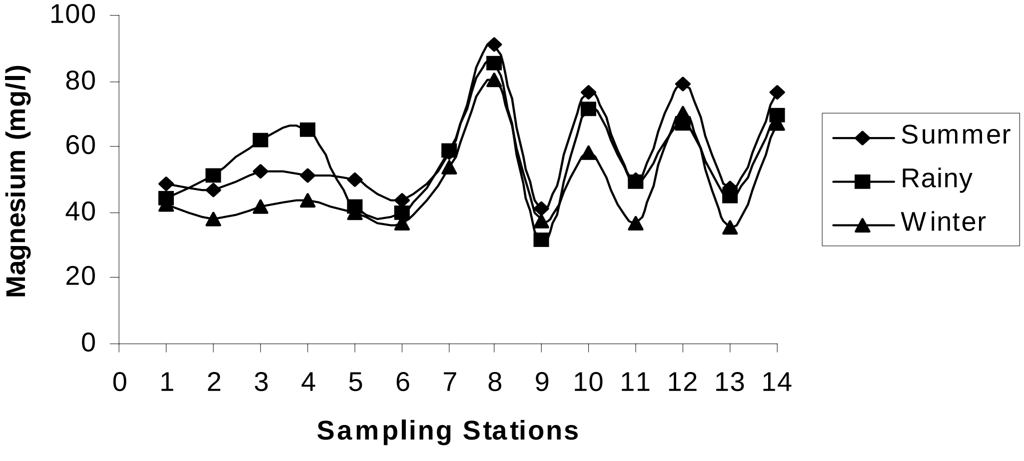


Fig. 2.17 Seasonal Variation in Magnesium during 1994-95 and 1995-96

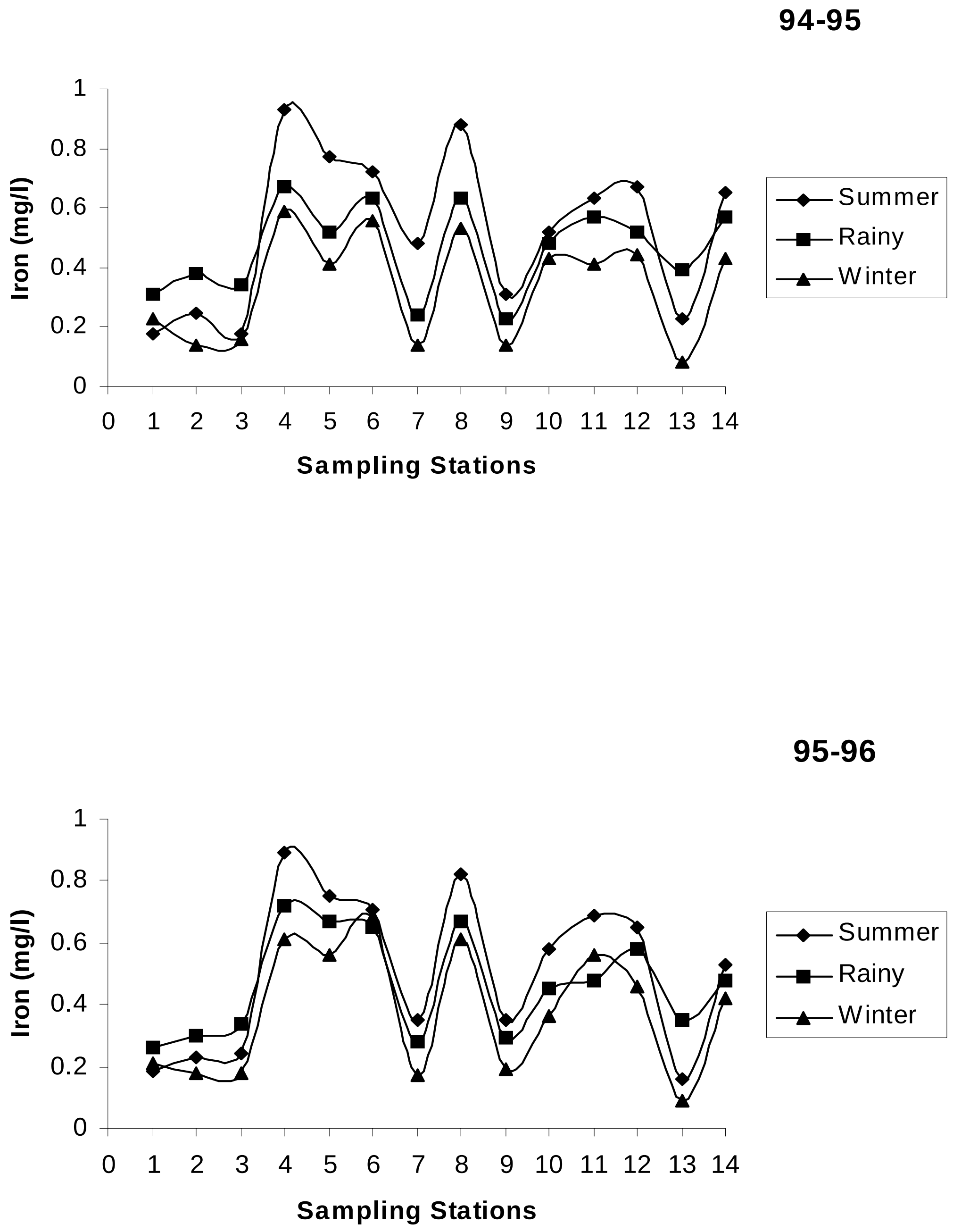


Fig. 2.18 Seasonal Variation in Iron during 1994-95 and 1995-96

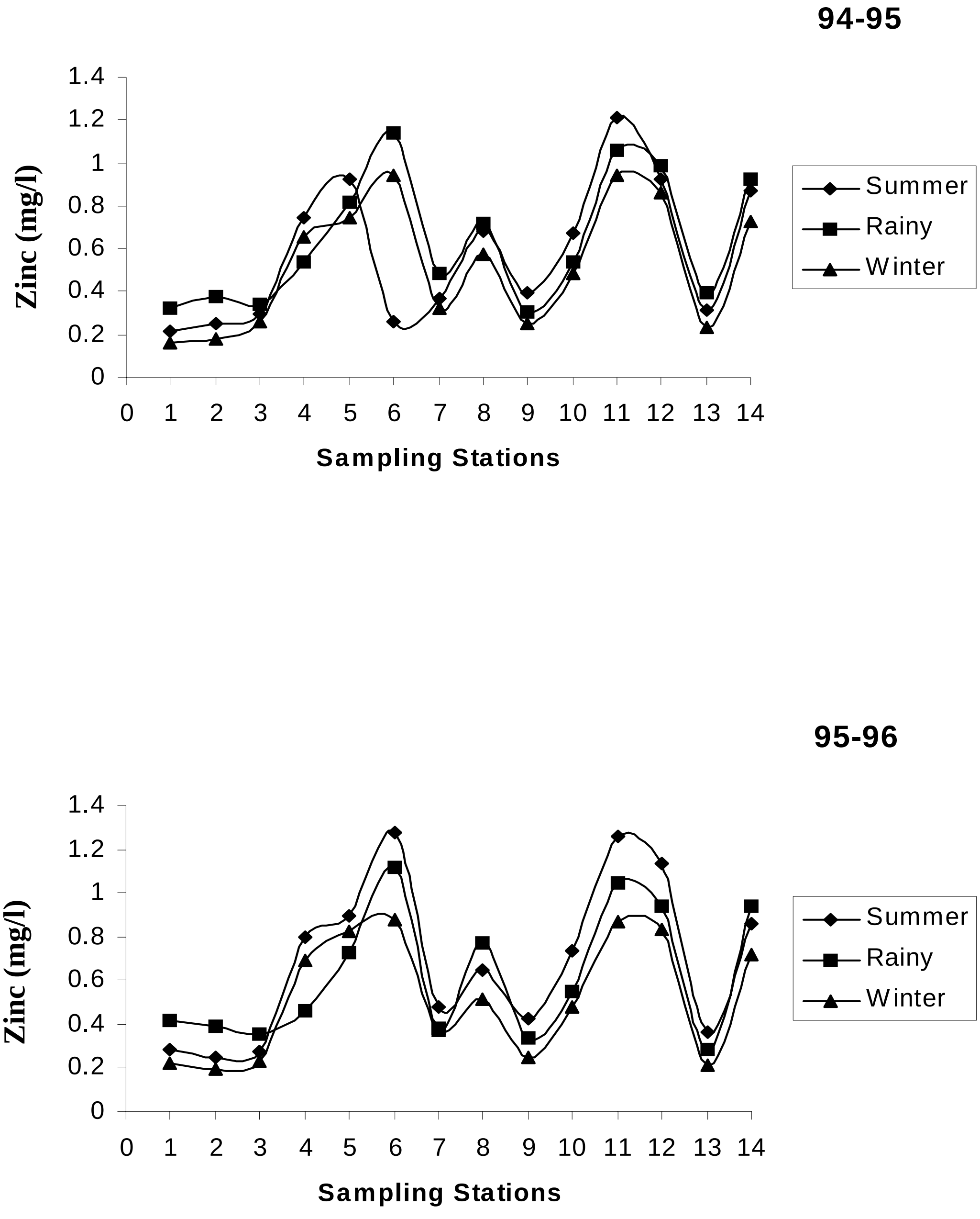


Fig. 2.19 Seasonal Variation in Zinc during 1994-95 and 1995-96

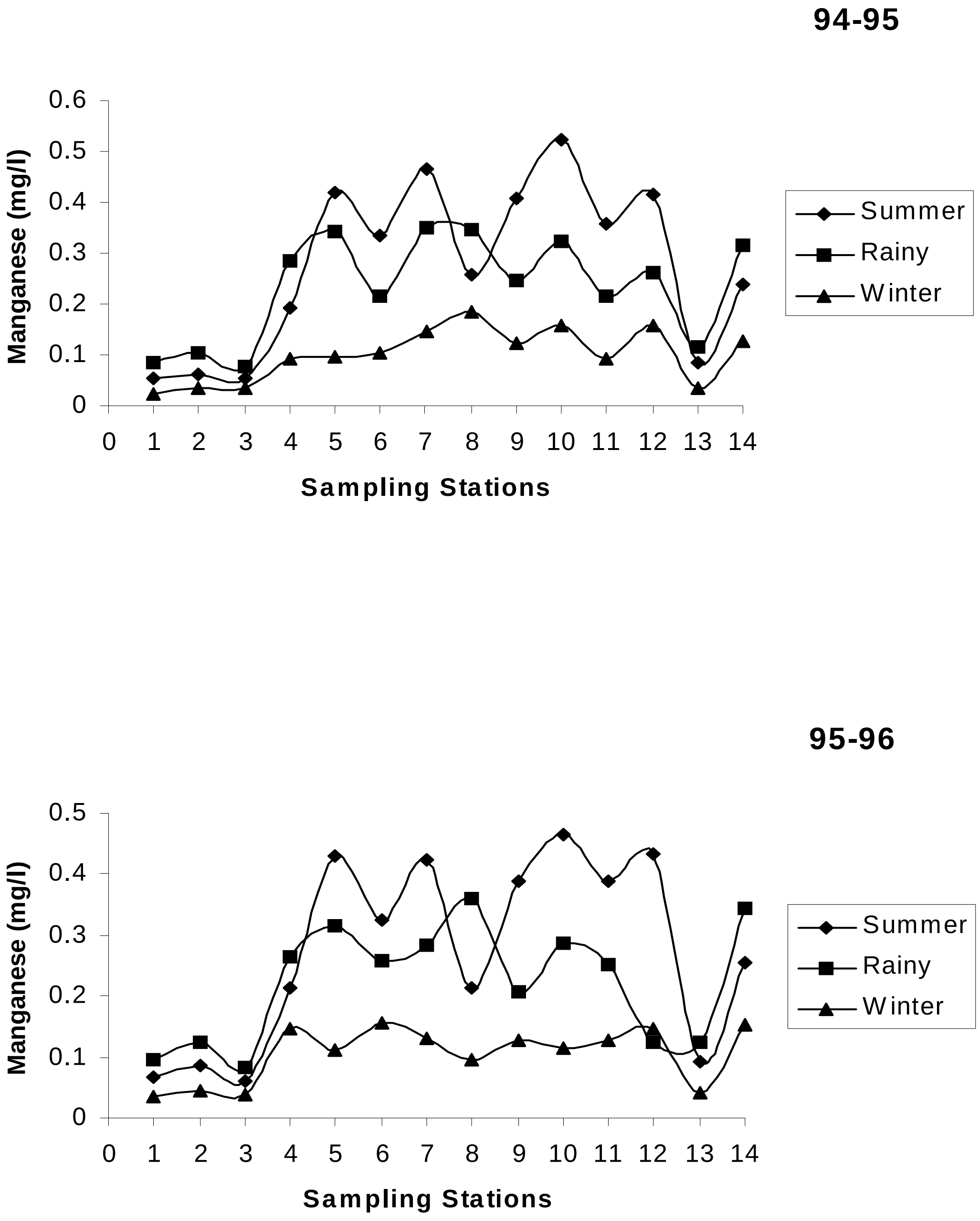
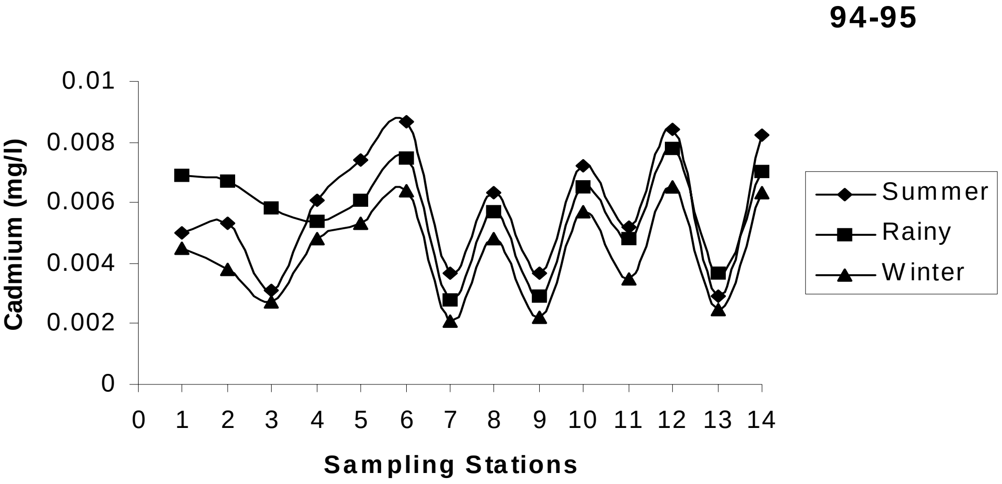


Fig. 2.20 Seasonal Variation in Manganese during 1994-95 and 1995-96



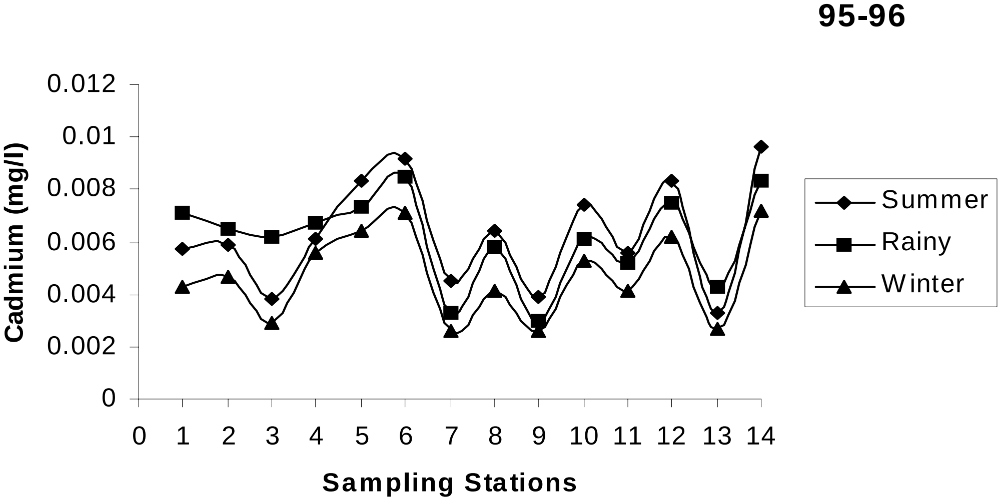


Fig. 2.21 Seasonal Variation in Cadmium during 1994-95 and 1995-96

CHAPTER – III

AIR POLLUTION

3.1.1 INTRODUCTION

Air is one of the extremely important things required for the substance of life on the planet earth. In addition to Nitrogen and Oxygen which make up 99% of the atmosphere, there are small amounts of other gases, minute droplets of various liquids and tiny particles of varieties of solids. We breathe various gases and particles in addition to Nitrogen and Oxygen. The atmosphere which is a gaseous envelope around the earth is divided to several concentric zones. Troposphere which contains the air that has a definite composition of different gases is closest to the surface of the earth. When due to some natural processes or human activities the concentration of substances other than Oxygen is increased in the air, it causes pollution of the atmosphere.

Air pollution has become an important factor of environmental degradation. Release of smoke from the chimneys of the industries, burning of fuels like coal, wood as well as the exhausts from automobiles leads to air pollution. In the modern times, rapid industrialization and use of automobiles for transport to cope with the growing demand of the growing human population have become the major sources of air pollution.

3.1.2 SOURCES OF AIR POLLUTION

The sources of air pollution can be either natural or artificial. The natural sources of air pollutants include forest fires, wind erosion of soil, volcanic eruption, evaporation of volatile organic matter, bacterial decomposition and so on. Most of the potential air pollutants artificially added to the atmosphere due to human activities including the burning of fossil fuels in power plants and industries (regarded as stationary sources) and in motor vehicles (regarded as mobile sources). Some of the principal sources of air pollution are given below :

1. Most of the industries release several air pollutants like CO_2, CO, Nitric Oxide, Nitrous Oxide and different Hydrocarbons. The textile industries release a lot of cotton dust to the atmosphere. The industries involved in the production of Chemical, Fertilizers and Pesticides release Chloride, Fluorine, Naphtha Vapour, Ammonia etc. in addition to Particulate Matter.
2. The coal-based thermal power plants release a lot of Fly Ash and Sulphur Dioxide.
3. The burning of fossil fuels produce Carbon Dioxide, Carbon Monoxide, Sulphur Dioxide, Oxides of Nitrogen and Metallic Traces.
4. Automobile exhausts contain Carbon Monoxide, Oxides of Nitrogen and Hydrocarbons, 3,4 – Benzypyrene is being produced due to incomplete combustion.
5. The Chlorofluorocarbons are released to the atmosphere from air conditioners and refrigerators and pollute the air.
6. Decomposition of organic wastes releases a lot of gases to the atmosphere which also contribute to its pollution.
7. Due to mining activities and crushing of stones, a lot of Particulate Matter and dust is released to the atmosphere.

3.1.3 AIR POLLUTANTS

The air pollutants can be classified as primary or secondary pollutants. The primary air pollutants are harmful chemicals which directly enter the air due to natural events of human activities. When any Carbon containing substance is burnt, it will produce Carbon Dioxide upon complete burning or Carbon Monoxide when burned partially.

($C+O_2 \longrightarrow CO_2$ or $2C + O_2 \longrightarrow 2CO$)

Another primary air pollutant is Sulphur Dioxide which is emitted to the air by volcanic eruption or burning of fuels which contain Sulphur impurities ($S + O_2 \longrightarrow SO_2$). A secondary air pollutant is a harmful chemical produced in the air due to chemical reaction between two or more components. That is primary pollutant combines with some component of the atmosphere to produce a secondary pollutant. For example, Sulphur Dioxide can combine with oxygen to form Sulphur Trioxide ($2SO_2 + O_2 \longrightarrow 2SO_3$. This SO_3 can react with water vapour in the atmosphere to produce Sulphuric Acid ($SO_3 + H_2O \longrightarrow H_2SO_4$). This various primary air pollutants can be grouped under five major categories viz. Oxides of Carbon, Oxides of Nitrogen, Sulphur Dioxide, Hydrocarbons and Aerosols.

Carbon Dioxide

Green plants use Carbon Dioxide for the synthesis of Carbohydrates. Dry air contains 0.03 percent (v/v) of Carbon Dioxide. In the recent years, the concentration of this gas is increasing in the atmosphere because of heavy industrialization and burning of natural fuels. Carbon Dioxide was not considered as an air pollutant, since it is a useful gas and its concentration was constant in the atmosphere. But since the concentration of this gas is constantly increasing, it is also considered as an air pollutant in recent times. Deforestation, along with heavy industrialization is the reason for the increase in the concentration of this gas in the air. Forests, with lots of plants in them, are responsible for the removal of Carbon Dioxide from the atmosphere due to Photosynthesis. As the forest cover is being depleted due to deforestation, the Carbon Dioxide concentration is gradually increased in the atmosphere.

Because of an increase in the Carbon Dioxide load in the atmosphere, the heat radiated from the surface of the earth is absorbed by from the Carbon Dioxide molecules and thus leads to global warming. This is called Green House Effect.

Carbon Monoxide

It is colourless, odourless toxic gas. The gas is produced by the incomplete combustion of carbon – rich fuels when they burn with insufficient Oxygen. The gas is produced by the incomplete combustion of coal and from internal combustion engines. Furnaces, thermal power plants and factories release a lot of Carbon Monoxide to the atmosphere. It is reported that, Carbon Monoxide is converted to Carbon Dioxide in the lower stratosphere by the reaction ($OH + CO \longrightarrow CO_2 + H$). Carbon Monoxide can combine with Hemoglobin to form Carboxyhemoglobin and reduce its Oxygen carrying capacity. Since Carbon Monoxide has greater affinity than Oxygen to occupy the coordination position of Oxyhemoglobin. It can remove Oxygen from Oxyhemoglobin even at low partial pressure.

$HbO_2 + CO \longrightarrow Hb\,CO + O_2$

Sulphur Dioxide

It is a colourless gas with a pungent and suffocating odour. The gas is produced by the combustion of fossil fuels. In the atmosphere, Sulphur Dioxide may combine Oxygen and Water to form Sulphuric Acid (H_2SO_4) leading to Acid Rain. Oxidation of Hydrogen Sulphide, which is given off decaying organic matter, also produces Sulphur Dioxide.

Exposure to Sulphur Dioxide down the ciliary’s movement of the respiratory tract of man and other animals. Continuous inhalation of this gas causes acute respiratory problems and headache. This gas can easily get into plants through their stomata. Continuous exposure of plants to this gas causes leaf biotchning, necrosis and loss of yield.

Sulphur Dioxide reduces the mechanical strength of paper. In humid conditions it hydrolyses the cellulose in the paper. Lime Stone and Marble are affected by this gas when the relative humidity is high. This gas leads to the corrosion of Iron and Steel and other metals. It also hydrolyses the leather protein in humid conditions.

Oxides of Nitrogen

The chief source of Nitrogen Oxides, which are also major primary air pollutants is automobile exhausts. Both Nitric Oxide (NO) and Nitrogen Dioxide (NO_2) are harmful to plants at low concentration and to animals at higher concentration. Nitric Oxide can combine with Atmospheric Oxygen to form Nitrogen Dioxide ($2NO + O_2 \longrightarrow 2\,NO_2$). Nitrogen Dioxide can dissociate to NO and Atomic Oxygen by ultraviolet radiation. Nitrogen Dioxide can readily combine with water to form Nitric Acid which forms a part of Acid Rain.

Particulate Matter

Particulate Matter includes the air pollutants which may be in the form of solid particles and liquid droplets called Aerosol. Natural dust forms about 50% of the total mass of Particulate Matter in the air. Diesel automobiles produce none of these Particulate Matters than the petrol vehicles. Asbestos mining, foundries, stone crushers, glass manufacturing units, cement factories, forest fires and volcanic eruptions increase the concentration of Particulate Matter in the air. The fine Particulate Matters are more harmful to human health than the coarse Particulate Matter. Man of these Particulate Matters when inhaled cause silicosis and lung cancer in man.

3.1.4 EFFECTS OF AIR POLLUTION

Air pollution has numerous harmful effects on human health. The type and severity depends on the nature and concentration of pollutants in the air. Since we inhale air and along with it the pollutants, they damage the respiratory system leading to bronchitis, silicosis, lung cancer etc. Certain gases may cause headache, allergies, nausea etc.

In many plants exposures to air pollutants lead to the loss of waxy coating from their leaf blades resulting in excessive loss of water. Exposures to such pollutants also cause necrosis of the leaves. The pollutants may enter through the stomata and bring about physiological disorders in the plants. May pollutants even induce premature leaf shedding and damage the flowers and fruits.

Chlorofluorocarbons are primarily responsible for depletion of the Ozone layer. Ozone acts as a screen and prevents the harmful ultraviolet radiation to reach the earth's surface. Once man is exposed to the harmful radiation there is chance of suffering from skin cancer. Further, it may lead to the increase in the incidence of eye cataract, severe sunburn and suppression of immune system.

Increase in the concentration of Greenhouse gases in the atmosphere leads to global warming. This may have disastrous effects on plant and animal life in the long run.

Many gaseous pollutants like the Oxides of Sulphur and Nitrogen combine with water vapour in the atmosphere cause Acid Rain. Acid Rain although may affect plants and vegetation, it also damages metallic and stone objects.

3.2 LITERATURE REVIEW

The rapid industrialization leading to urbanization, unplanned and excessive exploitation of natural resources have been causing pollution problems in cities and towns of developing countries. Man made and natural sources of emissions have polluted the air with toxic substances. The problem of air pollution is mainly affecting the urban environment all over the world, (Ledderbetter[17] 1973). Emissions (Hammerle[12] 1968, Alam[1] *et al*, 1999) may be categorized mainly as stationary and mobile sources which include all the activities in an urban environment. The ambient air quality is being monitored regularly in several cities and town throughout the world. The data on the air quality will help taking appropriate step to control the increasing concentration of pollutants.

Meenakshi and Mahadevan[22] (1991) studied the ambient air quality in Madurai City of South India and found that the SPM concentration varied from 200 to 500 $\mu g / m^3$, NO_x from 50 to 170 $\mu g / m^3$ and SO_2 from 10 to 25 $\mu g / m^3$. Bansal[3] (1996) studied the ambient air quality of Bhopal city with reference to NO_x concentration in Commercial, Industrial and Residential Areas during 1992-94, the maximum values was recorded as 96.4 $\mu g / m^3$, 66.3 $\mu g / m^3$, 53.5 $\mu g / m^3$ respectively and the monthly average values were well below the prescribed standards. Sarangi and Mishra[34] (1997) studied the Ambient Air Quality of Jyotivihar, Orissa in terms of SPM, SO_2 and NO_x during December – 1994 to November – 1995. The minimum and maximum values were 82.995 $\mu g/m^3$ and 182.7 $\mu g/m^3$ for SPM, 4.62 $\mu g/m^2$ and 25.74 $\mu g/m^3$ for SO_2 and 4.39 $\mu g/m^3$ and 16.89 $\mu g/m^3$ for $NO_{x.}$ All these values were within the permissible limit prescribed by Central Pollution Control Board. Gupta[11] *et al* (1998) studied Ambient Air Quality of Paonta Sahib (H.P) during 1994 – 96 and monthly average values of SPM and NO_x were well below the prescribed standards in Industrial Area.

Ravichandran[33] *et al* (1998) observed the Ambient Air Quality (SPM, SO_2 and NO_x) of Tiruchirapalli at four sampling stations and the SPM levels exceeded the two sampling stations (Bishop Harber College and Thillai Nagar) Where as the SO_2 and NO_x level also exceeded in Thillai Nagar sampling station. Alam[1] *et al* (1999) studied the ambient air quality at roadside in Dhaka City and estimated the Air Quality Index (AQI) at various locations of the city are more than seventy percent are severely polluted and rest of the location are highly polluted. This environmental condition has very serious implications on the health of the inhabitants of the city, particularly the commuters, causing eye and skin irritation, headache, breathing problems etc.

Joshi and Mishra[15] (1998) studied the Ambient Air Quality at Indore, Madhya Pradesh during 1991 to 1995. The values of SPM exceed the prescribed standards for Commercial and Residential Areas for most of the time, while they were mostly within the limits in the Industrial areas. The concentration of SO_2 and NO_x are far below the prescribed maximum limits at all places.

Ambient Air Quality in respect to SPM, $NO_{x,}$ SO_2 and CO was monitored over various parts of Calcutta by Mandal[20] (2000). Urbanized areas of the western part of Calcutta was the most polluted area compared to other areas which is highly urbanized, closed to the Howrah Industrial Sector and with high density of population which lead to greater concentration of pollutants in this area. Meenambai and Akil[23] (2000) studied the Ambient Air Quality of Coimbatore City at ten (10) important junctions and was found the level of SPM exceeds the ambient air quality standard of CPCB and SO_2 and NOx were well within the limits, which is due to Traffic congestion, increased human activities and high rise buildings, existing parallel to each other. The remedial measures suggested includes banning old technology vehicles, upgrading 2 stroke engines to 4 stroke engines, using catalytic converters, planting more trees along the road sides and proper Traffic regulation.

Dayal and Nandini[8] (2000) studied the Ambient Air Quality for 10 congested areas in Bangalore City. The results indicate that in six of the ten congested areas, the SPM values are above the limit, while Oxides of Nitrogen (NO_x) and SO_2 are within the prescribed limit in all the areas and the Air Quality Index (AQI) for all places has been observed that in 1 out of the 10 places, the air is clean, in 4, it can be classified as light air pollution and the remaining 5 places, it is moderately polluted. Chandrasekar[7] *et al* (2002) monitored the air quality parameter (SPM, SO_2, and NO_x) at the three different locations in and around Tuticorin City at weakly intervals for a year. The Air Quality Index varies from maximum 27.9 (fairly clean) to 9.00 (clean). The concentration of SO_2 and NO_x were high during winter, where as SPM level was high in the Commercial cum – Residential Area during summer. Senthilnatihan and Rajan[35] (2002) studied the SPM concentration on Chennai City during the year 2000, at five sampling stations across the city and monthly average SPM concentration was found to lie above National Ambient Air Quality Standard values. Mukherjee[26] *et al* (2003) studied the SPM, SO_2 and NO_x in ambient air around Alluminium Smelter of Angul – Talcher belt in central Orissa during February and August – 1996. Higher values of SPM, SO_2 and NO_x were obtained on February as prescribed by CPCB standards. Sharma and Prasad[38] (2004) studied the SPM Concentration in Chandigarh for the period of June – 1993 to May – 1994 and found that minimum 133 μgm / m^3 to maximum 227μgm/m^3.

3.3 WORK DONE BY AUTHOR

The present survey was carried out during the period starting from Jun-1995 to May 1997. Literature survey shows that, no systematic, extensive studies have been conducted of air pollution in Bondamunda area. Air, Born Dust, Suplphur Dioxide, Oxides of Nitrogen, which arise due to coal burning, causes toxic effect on human and its environment. So the analyses of air pollutants are of prime importance. As the study involves industries like Steel Plant, Fertilizer Plant, IDL and many more small scale industries, the Ambient Air sampling was done for the emitted particulate matters and gaseous of these industries. Sampling was done by high volume sampler with attachment for different gases. The analysis of size distribution of the particulate mass was done by high volume lascade impactor. Since the gaseous pollutants are SPM or fly-ash are supposed to move in the direction of wind recording was also done for wind speed and wind direction by recorder.

Relative humidity in air (morning and afternoon), Temperature, Rainfall and number of Rainy Days in year play an important role in air pollution. Therefore regular and constant readings were taken to measure all these parameters through the year. The high volume sampler was set accordingly and air sampling was done in all the four directions. The sampling and analysis of SPM, SO_2 and NO_x was done by standard methods (APHA[2] 1977, Gandhi and Khopkar[9] 1989, Lodge[19] 1993, Kartz[16] 1969).

3.4 METHODOLOGY

i) Analysis of SPM

Air was drawn into a covered housing and through a pre weight Whatman GF / A filter paper for 24 hours in month, in a high volume sampler by means of a high flow rate blower at a flow rate of 1.0 m^3 / min. The mass concentration of SPM in the Ambient Air (µgm / m^3) was calculated by measuring the mass collected and volume of air sampled.

The conc. of dust = $\frac{Wx10}{VxT}\mu gm/m^3$

Where, V = Average flow rate in m^3 / min

T = Total period of running time in minutes

W = difference in final and initial weight of filter paper in gms.

Sulphur Dioxide (SO_2)

Air sample was bubbled through 15 ml absorbing media i.e. Sodium Tetrachloramerqurate (0.1M) with acid bleached Pararosaniline and Formaldehyde. The red purple colour of Pararosniline methyl Sulphonic Acid developed was determined Spectrophotometrically after half an hour and optical density was measured at 560 nm.

SO_2 in μgm / m^3 was calculated as given below.

$$SO_2\ \mu gm / m^3 = \frac{\mu gm\ SO_2}{Volume\ of\ \ air\ \ sample\ (V)}$$

Oxide of Nitrogen (NO_x) :- (Jacobs Hochheiser Method)

Since Nitric Oxide is a positive interferent, the presence of NO_2 can increase the NO response by 5 – 15 % of the NO sampled. So both these gases are taken as Oxides of Nitrogen. Nitrogen Dioxide was collected by bubbling air through 50 ml of the absorbing media (i.e. Sodium Hydroxide and Sodium Arsenite solution). The optical density was taken for the Azo dye coloured developed in the solution and concentration was calculated using the calibration curve.

$$\mu gm\ NO / m^3 = \frac{\mu gm\ NO\ in\ ml\ \ x\ 50}{V\ \ x\ 0.82}$$

50 = volume of absorbing media

V = Volume of the air sampled

0.82 = factor for collecting efficiency.

3.5 RESULTS AND DISCUSSION

The monthly values for Suspended Particulate Matter (SPM) for the three sampling stations S_1, S_2 and S_3 are given in **Table 3.1**. The complete results (monthly values) for Sulphor Dioxide and Oxides of Nitrogen are given in **Table 3.2** and **3.3** respectively. The average seasonal values of SPM, SO_2 and NO_x at three sampling stations are given in **Table 3.4, 3.5**, and **3.6** respectively. Ambient Air Quality standards of Central Pollution Control Board (CPCB) are given in **Table 3.7**. Further, the minimum and maximum Temperature during each month and the predominant wind directions in each month are given in **Table 3.9**. A carefully study of all these tables reveals many interesting points as follows.

SUSPENDED PARTICULATE MATTER (SPM)

Out of all the three sampling stations, the highest concentration of Suspended Particulate Matter (SPM) was observed at sampling station S_1. The reason for such higher concentrations of quite obvious, as can be seen form the **Table 3.1** and **Fig. 1.2**, this sampling station is Residential cum Industrial Area situated very close to the Steel Plant and also does not have any barrier to obstruct the emissions form the Steel Plant. The highest concentration 745.1 $\mu g / m^3$ was observed between July – 95. The next higher concentration of SPM was observed at sampling station S_2 which is Residential cum Traffic Area. The maximum concentration 442.6 $\mu g / m^3$ was observed between Jun – 96 and the minimum 62.5 $\mu g / m^3$ between July -96. The sampling station also does not have any natural or artificial barrier which can obstruct the smokes and gases form the Steel Plant. Such wide variations in concentrations at these two sampling stations (which have almost similar topographic features) were probably due to their distances from the Steel Plant. Next lower concentration level was observed at sampling station S_3. This sampling station is a residential situated in a rural area. The maximum concentration 320.0 $\mu g / m^3$ observed between May – 96 and the minimum 54.8 $\mu g / m^3$ was observed between August – 95.

Comming over to the effects of climatic conditions on the SPM at Bondamunda area, the results can be best interpreted as follows. We have mentioned earlier that, there are three seasons are experienced, and these are (1) winter (November to February) (2) summer (March to Jun) (3) rainy (July to October). Average concentrations of SPM in these three season at three sampling stations during the year 1995 – 96 and 1996 – 97 are given in **Table 3.4**. From the Table, it is clear that, the concentration of SPM was highest in the dry and hot months i.e. summer season. The sampling station S_1 and S_2 exceeds the limit (Residential Standard, 140 μg / m^3 (24 hrs) in all the seasons, where as in sampling station S_3, the limit exceeded only in summer seasion, such observations were reported by Singh and Sharma[36] (1991) also, which studying the Ambient Air Quality of some coal mining areas of Raniganj Coal Fields (India). However no general trend was observed for the minimum concentration. These observations are true for all the sampling stations covered during the survey period, June – 1995 to May -1997. This indicates that SPM concentrations in the Ambient Air of Bondamunda was due to Steel Plant, small and medium industries, house held activities, vehicular movements etc.

SULPHUR DIOXIDE

The highest concentration of Sulphur Dioxide was observed at sampling station S_1 during all the two years of the survey period. The minimum concentration was recorded at sampling station S_3. The reason for such observation was due to that, the sampling station S_1 is very close to the Steel Plant (and has no barrier between the survey area and Steel Plant) and therefore dust, smokes and gases of the Steel Plant directly affect this area. Sampling station S_3 is far away from the Steel Plant and purely residential, situated in a rural area. Due to this, a lower concentration of Sulphur Dioxide was recorded at this sampling station. The next higher concentration was observed at station S_2 which is residential cum traffic point and situated near marshalling yard and far away from Steel Plant. Monthly variation of SO_2 with three sampling stations can be given in **Fig. 3.2**.

Now coming to the average concentrations of SO_2 during the three seasons, the highest concentration of SO_2 was observed during the summer season. This indicates that, the concentration of SO_2 is highest in the dry and hot atmospheres. However, the lowest concentration was found either during the rainy or winter season. This observation was true for all the three sampling stations during the entire survey period as given in **Table 3.5**. The level of trends in concentration of SO_2 at various sampling stations indicate that, such observations are almost identical to the SPM and holds good for this parameter too.

OXIDES OF NITROGEN (NOx)

The complete results for Oxides of Nitrogen (NO_x) at the three sampling stations are given in **Table – 3.3**. A study of this Table reveals that, the trend observed for this parameter was almost identical to the parameter SPM and SO_2. Sampling station S_1 showed highest concentration and station S_3 showed lowest concentration of NO_x, where the sampling station S_1 is situated near the Steel Industries and sampling station S_3 is located far away from Steel Plant and situated in a rural area. Monthly variation of NO_x with three sampling stations can be given in **Fig. 3.3**.

Now by grouping the months into seasons viz. Jun to September (rainy), October to January (winter) and February to May (summer). It was observed that, the period February to May (summer season) shows the highest concentration of NO_x at all the sampling stations. That means, NO_x like SPM and SO_2 also recorded highest concentrations of Ambient Air during dry and hot seasons. But no particular pattern was observed for the minimum concentration of NO_x. At some sampling stations, the winter season showed minimum concentration which some other stations showed minimum concentration during rainy season. The exact values are given in **Table 3.6**.

AIR QUALITY INDEX (AQI)

Air quality index is calculated following Tiwari and Ali[39] method. The quality rating of each parameter is obtained by

$$q = 100 \text{ X } \frac{V}{V_s}$$

Where q is the Quality Rating

V = is the observed values of the parameter and

V_s = is the standard value recommended for the parameter

If 'n' numbers of parameters are considered, the Geometric Mean of these "n" number of Quality Rating is found out and this is as Air Quality Index (AQI). Based on the AQI, air quality is categorized (Mudri[24] 1990) which is given in **Table 3.8**. Monthly variation of Quality Rating for SPM, SO_2 and NO_x with respect to Residential Standards (24 hrs) of CPCB along with air quality category for the three sampling stations S_1, S_2 and S_3 are given in **Table 3.10**, **3.11** and **3.12** respectively. It is clear from **Table 3.10** that the minimum value of AQI is 18.22 which is clean category obtained during July – 1995 to maximum 293.0 which is severely polluted obtained during June – 1996. The reason is that, the sampling station S_1 is situated near the Steel Plant and various small scale industries are located. The AQI varies from minimum 14.41 (Clean Category) to maximum 99.1 (Polluted Category) which is obtained during August – 1996 and May – 1997 respectively at sampling station S_2. At sampling station S_3, the maximum value of AQI is 59.61 which is moderately polluted during May – 1997 and the minimum value is 11.15 which is clean category during August – 1995. Variation of AQI with three sampling stations is given in **Fig. 3.4**.

For better understanding, now by grouping the months into seasons i.e. Rainy, Winter, and Summer, it was observed that, the summer season shows highest concentration than winter season and the rainy season has the lowest value to AQI at all the sampling stations (**Table-3.13**). In summer season the maximum value of AQI is 117.24 (Heavily Polluted) at sampling station S_1 during 1996-97 to minimum 47.34 (Fairly Clean) at sampling station S_3 during 1995-96 respectively. The sampling station S_1 is heavily polluted category in both the years because high values of Particulate Matter, this might be due to the fact that, the dry ground dust got lifted up by the wind, vehicular movements and nearby the industrial area. In winter season, the maximum value is 57.2 (Moderately polluted to minimum 24.42 (Clean) at sampling station S_1 during 1995 – 96 and sampling station S_3 during 1996-97 respectively. In Rainy season, the AQI values varies from maximum 55.86 (Moderately Polluted) at sampling station S_1 during 1996-97 to minimum 19.76 (Clean) at sampling station S_3 during 1995-96.

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Table 3.1 Monthly Values of Suspended Particulate Matter (SPM) in μg/m^3 at three Sampling Stations

Year	Month	Concentration of SPM (μg/m^3)		
		S_1	S_2	S_3
1995	June	706.5	434.6	312.6
	July	75.2	173.2	105.3
	August	82.3	68.1	54.8
	September	138.6	103.8	67.5
	October	235.3	237.5	98.7
	November	232.5	225.6	101.3
	December	258.3	268.5	129.8
1996	January	305.6	386.2	196.5
	February	360.5	389.6	265.6
	March	406.7	396.1	275.1
	April	596.5	425.0	268.8
	May	742.3	431.9	320.0
	June	745.1	442.6	315.4
	July	87.5	62.5	62.1
	August	92.6	83.7	74.7
	September	131.5	121.2	83.1
	October	195.2	225.3	100.2
	November	224.1	234.5	115.0
	December	218.7	275.0	140.6
1997	January	325.0	342.1	173.1
	February	382.6	397.4	259.3
	March	475.7	405.6	285.6
	April	571.0	437.5	308.7
	May	724.1	475.2	326.4

Table 3.2 Monthly Values of Sulphur Dioxide (SO_2) in $\mu g/m^3$ at three Sampling Stations

Year	Month	Concentration of SO_2 ($\mu g/m^3$)		
		S_1	S_2	S_3
1995	June	40.6	27.9	10.4
	July	5.2	4.1	3.2
	August	7.3	5.8	3.7
	September	9.7	7.2	4.2
	October	17.8	9.7	4.6
	November	21.4	10.6	5.3
	December	19.6	10.4	7.1
1996	January	24.7	12.8	9.5
	February	30.8	16.2	9.8
	March	33.6	24.1	10.5
	April	42.5	33.4	12.1
	May	47.0	38.1	15.7
	June	41.7	26.0	10.2
	July	6.2	12.5	4.7
	August	11.5	4.6	3.5
	September	12.7	6.8	4.8
	October	18.1	9.4	7.2
	November	19.7	11.6	5.3
	December	20.5	12.8	6.5
1997	January	28.2	13.5	9.2
	February	32.5	15.8	11.8
	March	35.7	28.6	12.1
	April	40.6	36.2	13.5
	May	48.2	39.4	16.4

Table 3.3 Monthly Values of Oxides of Nitrogen (NO_x) in μg/m^3 at three Sampling Stations

Year	Month	Concentration of NO_x (μg/m^3)		
		S_1	S_2	S_3
1995	June	24.6	22.8	11.0
	July	7.9	4.2	2.8
	August	8.5	6.3	3.2
	September	9.1	8.1	4.7
	October	13.4	8.4	5.5
	November	14.6	8.7	8.2
	December	19.5	10.9	10.5
1996	January	22.7	12.5	10.6
	February	32.4	17.4	13.7
	March	36.5	20.7	15.5
	April	41.6	22.0	15.8
	May	45.2	25.4	18.2
	June	37.5	19.7	16.5
	July	10.7	3.5	3.1
	August	12.4	6.0	3.7
	September	13.7	7.5	5.2
	October	13.5	8.4	5.5
	November	15.8	8.5	8.7
	December	20.6	11.8	7.2
1997	January	20.7	13.6	9.6
	February	30.6	19.1	12.7
	March	31.9	33.6	14.2
	April	43.6	24.5	16.5
	May	47.8	28.7	18.4

Table 3.4 : Average Seasonal Values of SPM in μg/m^3 at three Sampling Stations During 1995-96 and 1996-97.

Year	Season	Average Concentration of SPM (μg/m^3)		
		S_1	S_2	S_3
1995-96	Rainy	250.65	194.925	135.05
	Winter	257.925	279.45	131.57
	Summer	526.5	410.65	282.37
1996-97	Rainy	264.17	177.5	133.825
	Winter	240.775	269.225	132.225
	Summer	538.325	428.925	295.0

Table 3.5 Average Seasonal Values of SO_2 in μg/m^3 at three Sampling Stations During 1995-96 and 1996-97.

Year	Season	Average Concentration of SO_2 (μg/m^3)		
		S_1	S_2	S_3
1995-96	Rainy	15.7	11.25	5.37
	Winter	20.87	10.87	6.62
	Summer	38.475	27.95	12.02
1996-97	Rainy	18.025	12.475	5.8
	Winter	21.625	11.825	7.05
	Summer	39.25	30.0	13.45

Table 3.6 Average Seasonal Values of NO_x in μg/m^3 at three Sampling Stations During 1995-96 and 1996-97.

Year	Season	Average Concentration of NO_x (μg/m^3)		
		S_1	S_2	S_3
1995-96	Rainy	15.525	10.35	5.425
	Winter	17.55	10.125	8.7
	Summer	38.925	21.375	15.8
1996-97	Rainy	18.525	9.175	7.125
	Winter	17.65	10.575	7.925
	Summer	38.475	23.975	15.45

Table 3.7 Ambient Air Quality Standards of Central Pollution Control Board (CPCB).

Sampling Station	SPM (μg/m^3)	SO_2 (μg/m^3)	NO_x (μg/m^3)
Industrial Area	500 (8 hr)	120 (8 hr)	120 (8 hr)
	300 (24 hr)	80 (24 hr)	90 (24 hr)
Residential Area	200 (8 hr)	80 (8 hr)	80 (8 hr)
	140 (24 hr)	60 (24 hr)	60 (24 hr)
Sensitive Area	100 (8 hr)	30 (8 hr)	30 (8 hr)
	70 (24 hr)	20 (24 hr)	20 (24 hr)

Table 3.8 Air Quality Categories Based on Air Quality Index (AQI).

Category	AQI of Ambient Air	Description of Ambient Air Quality
I	Below 10	Very Clean
II	Between 10-25	Clean
III	Between 25-50	Fairly Clean
IV	Between 50-75	Moderately Polluted
V	Between 75-100	Polluted
VI	Between 100-125	Heavily Polluted
VII	Beyond 125	Sevearly Polluted

Table 3.9 Minimum and Maximum Temperatures and Predominant Wind Direction Recorded on a Monthly Basis During the Period 1995-96 and 1996-97.

(E=East, W=west, N=North, S=South, SE= South East , NE=North East, NW= North West)

Year	Month	Temperatures in ^oC		Predominant Wind Direction
		Minimum	Maximum	
1995	June	23.6	42.3	SE
	July	22.8	37.8	NE
	August	22.1	34.5	E
	September	23.5	37.8	E
	October	19.4	36.3	NE
	November	15.1	36.2	N
	December	9.5	24.0	NE
1996	January	8.6	33.4	NE
	February	9.8	35.7	N
	March	14.8	37.8	NW
	April	17.3	40.5	SE
	May	24.8	45.6	S
	June	24.1	44.0	SE
	July	22.3	39.0	NE
	August	23.4	36.5	NE
	September	22.8	35.7	NE
	October	18.5	36.0	N
	November	14.0	33.2	N
	December	10.1	25.0	N
1997	January	6.8	30.1	NE
	February	10.4	36.5	N
	March	15.8	38.4	NW
	April	20.0	42.5	S
	May	25.4	46.7	S

Table 3.10 Monthly Variation of Air Quality Index (AQI) as per Residential Standards (24 hr) of CPCB at Sampling Station – S_1

Year	Month	Quality Ratings			Air Quality Index
		SPM	SO_2	NO_x	
1995	June	504.6	67.6	41.0	111.8
	July	53.7	8.6	13.1	18.22
	August	58.7	12.1	14.1	21.55
	September	99.0	16.1	15.1	28.87
	October	168.0	29.6	22.3	48.04
	November	166.0	35.6	24.3	52.36
	December	184.5	32.6	32.5	58.03
1996	January	218.2	41.1	37.8	69.72
	February	257.5	51.3	54.0	89.35
	March	290.5	56.0	60.8	99.63
	April	426.0	70.8	69.3	127.85
	May	530.2	78.3	75.3	146.21
	June	532.2	69.5	62.1	131.94
	July	62.2	10.3	17.8	22.5
	August	66.1	19.1	20.6	29.62
	September	93.9	21.1	22.8	35.61
	October	139.4	23.5	22.5	41.92
	November	160.0	32.8	26.3	51.67
	December	156.2	34.1	34.3	56.74
1997	January	232.2	47.0	34.5	72.2
	February	273.2	54.1	51.0	91.0
	March	339.7	59.5	53.1	102.38
	April	407.8	67.6	72.6	126.02
	May	517.2	80.3	79.6	148.96

Table 3.11 Monthly Variation of Air Quality Index (AQI) as per Residential Standards (24 hr) of CPCB at Sampling Station – S_2

Year	Month	Quality Ratings			Air Quality Index
		SPM	SO_2	NO_x	
1995	June	310.4	46.5	38.0	81.85
	July	123.7	6.8	7.0	18.05
	August	48.6	9.6	10.6	17.03
	September	74.1	12.0	13.5	22.89
	October	169.6	16.1	14.0	33.68
	November	161.1	17.6	14.5	34.51
	December	191.7	17.3	18.1	39.15
1996	January	275.8	21.3	20.8	49.62
	February	278.2	27.0	29.0	60.17
	March	282.9	40.1	34.5	73.14
	April	303.5	55.6	36.6	85.16
	May	308.5	63.5	42.3	93.92
	June	316.1	43.3	32.8	76.57
	July	44.6	20.8	5.8	17.52
	August	59.7	7.6	10.0	16.55
	September	86.5	11.3	12.5	23.03
	October	160.9	15.6	14.0	32.75
	November	167.5	19.3	14.1	35.72
	December	194.4	21.3	19.6	43.29
1997	January	244.3	22.5	22.6	49.89
	February	283.8	26.3	31.8	61.91
	March	289.7	47.6	39.3	81.52
	April	312.5	60.3	40.8	91.6
	May	339.4	65.6	47.8	102.09

Table 3.12 Monthly Variation of Air Quality Index (AQI) as per Residential Standards (24 hr) of CPCB at Sampling Station – S_3

Year	Month	Quality Ratings			Air Quality Index
		SPM	SO_2	NO_x	
1995	June	223.2	17.3	18.3	41.13
	July	75.2	5.3	4.6	12.23
	August	39.1	6.1	5.3	10.8
	September	48.2	7.0	7.8	13.8
	October	70.5	7.6	9.1	16.9
	November	72.3	8.8	13.6	20.5
	December	92.7	11.8	17.5	26.75
1996	January	140.3	15.8	17.6	33.9
	February	189.7	16.3	22.8	41.3
	March	196.5	17.5	25.8	44.6
	April	192.0	20.1	26.3	46.64
	May	228.5	26.1	30.3	56.53
	June	225.2	17.0	27.5	47.2
	July	44.3	7.8	5.1	12.07
	August	53.3	5.8	6.1	12.35
	September	59.3	8.0	8.6	15.97
	October	71.5	12.0	9.1	19.8
	November	82.1	8.8	14.5	21.8
	December	100.4	10.8	12.0	23.52
1997	January	123.6	15.3	16.0	31.1
	February	185.2	19.6	21.1	42.46
	March	204.0	20.1	23.6	45.9
	April	220.5	22.5	27.5	50.2
	May	232.8	27.3	30.6	57.93

Table 3.13 Seasonal Variation of AQI as per Residential Standards (24 hr) of CPCB at three Sampling Stations.

Sampling Station	Year	Season	Quality Ratings			AQI	Category
			SPM	SO_2	NO_x		
S_1	1995-96	Rainy	179.0	26.1	25.8	49.39	Fairly Clean
		Winter	184.2	34.8	29.2	57.2	Moderately Polluted
		Summer	376.0	64.1	64.8	116.02	Heavily Polluted
	1996-97	Rainy	188.7	30.0	30.8	55.86	Moderately Polluted
		Winter	171.9	36.0	29.4	56.66	Moderately Polluted
		Summer	384.5	65.4	64.1	117.24	Heavily Polluted
S_2	1995-96	Rainy	139.2	18.7	17.2	35.5	Fairly Clean
		Winter	199.6	18.1	16.8	39.29	Fairly Clean
		Summer	293.3	46.5	35.6	78.59	Polluted
	1996-97	Rainy	126.7	20.8	15.3	34.29	Fairly Clean
		Winter	192.3	19.7	17.6	40.54	Fairly Clean
		Summer	306.3	50.0	39.9	84.85	Polluted
S_3	1995-96	Rainy	96.46	8.9	9.0	19.76	Clean
		Winter	93.9	11.0	14.5	24.64	Clean
		Summer	201.7	20.0	26.3	47.34	Fairly Clean
	1996-97	Rainy	95.6	9.6	11.8	22.12	Clean
		Winter	94.4	11.7	13.2	24.42	Clean
		Summer	210.7	22.4	25.7	49.5	Fairly Clean

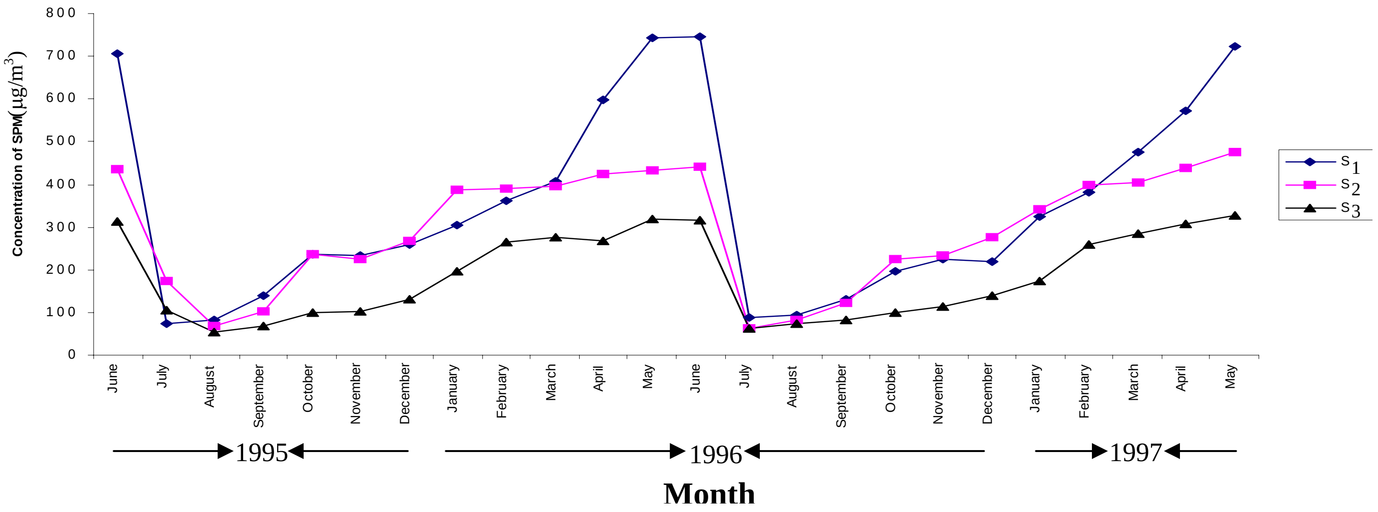

Fig. 3.1 Monthly Variation in Suspended Particulate Matter (SPM)

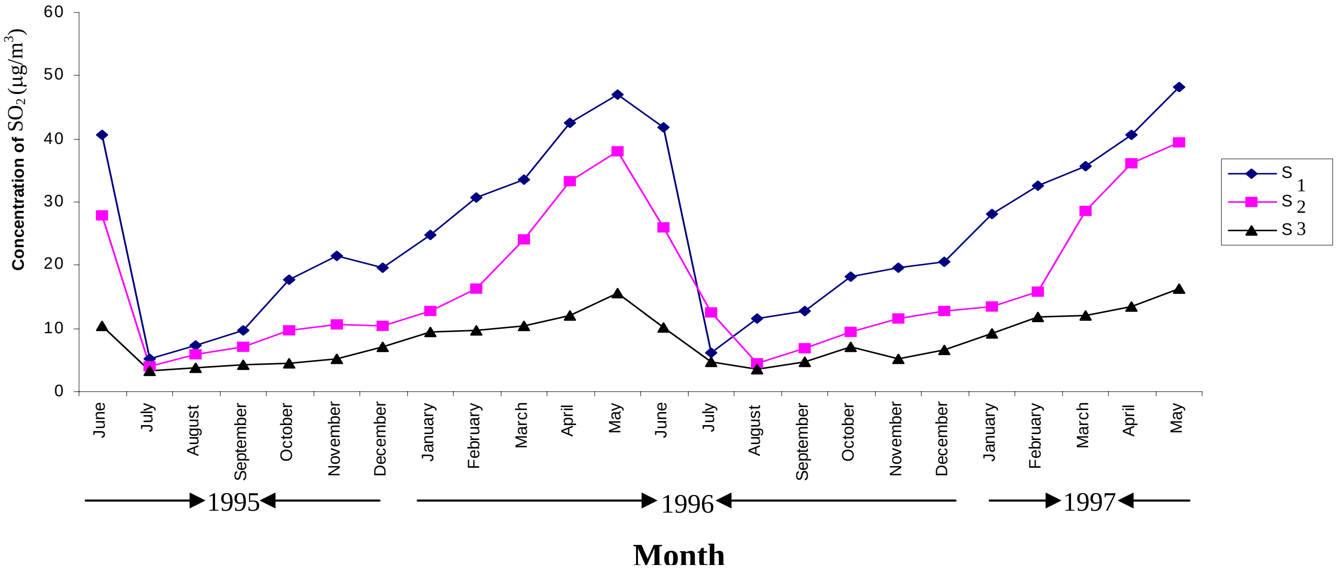

Fig. 3.2 Monthly Variation in Sulphur Dioxide (SO_2)

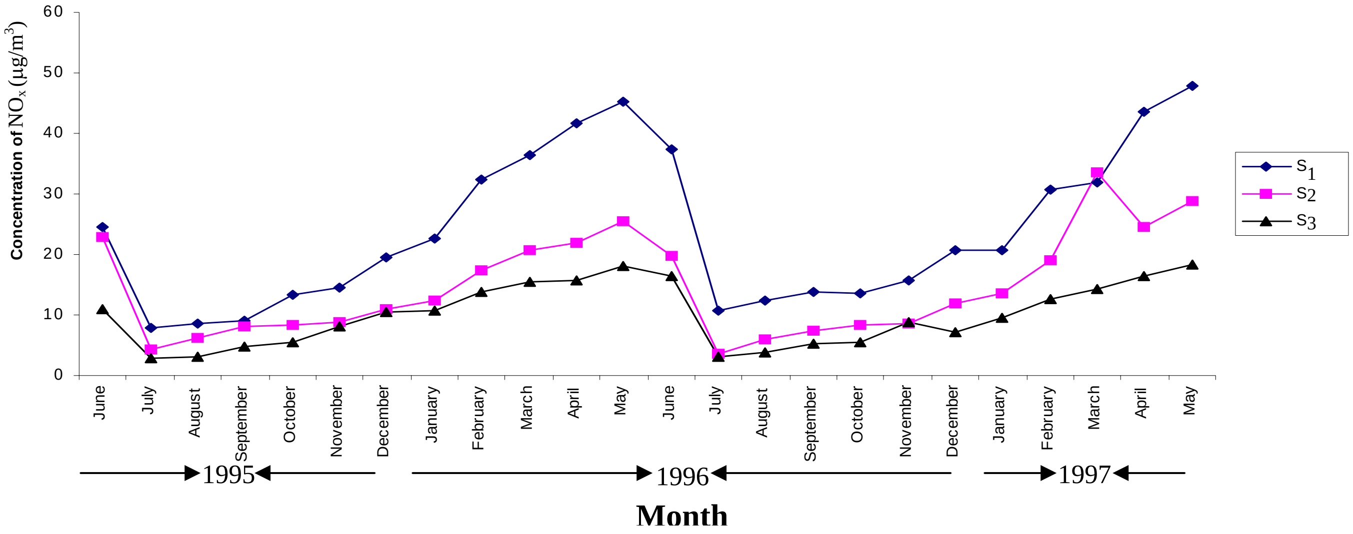

Fig. 3.3 Monthly Variation in Oxides of Nitrogen (NO_x)

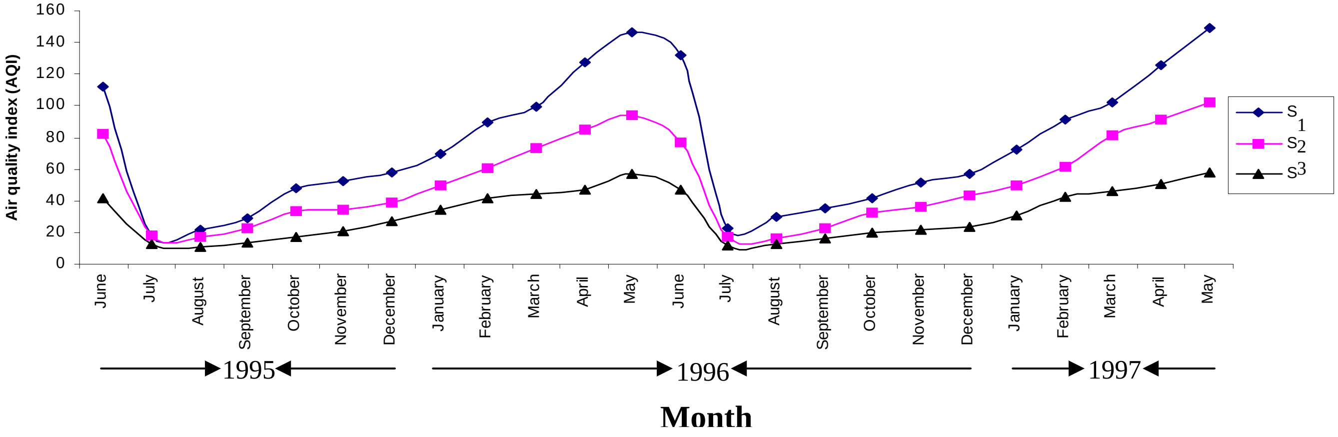

Fig. 3.4 Monthly Variation in Air Quality Index (AQI)

CHAPTER-IV NOISE POLLUTION

4.1.1 INTRODUCTION

Noise, commonly defined as unwanted sound, is an environmental phenomenon to which we are exposed before birth and through life. Noise can also be considered an environmental pollutant, a waste product generated in conjunction with various anthropogenic activities. Under the latter definition, noise is any sound, independent of loudness – that can produce an undesired physiological or psychological effect in an individual or group. These social ends include all of our activities – communication work, rest, recreation and sleep.

4.1.2 SOUND AND NOISE

The sound is a form of energy and requires medium, like gas, liquid or solid for propagation. The sound frequency is defined as the energy between 2-20,000 Hz. The 1200 Hz range of frequency is called frequency band which human being can hear and tolerate.

The intensity of sound can be determined with great precision and it is related to the amount of energy (sound) received/sec from the source of sound. The sound pressure level (SPL) is defined as :

Intensity level = 10 log (p/p_o)

Or SPL = 20 log (p/p_o) dB

Where p is measure of pressure and p_o is reference pressure usually 2×10^{-5} N/m^2.

4.1.3 SOURCES OF NOISE POLLUTION

Noise is either natural such as thunder or man made. The important sources of man made noise in developed urban areas are mechanized automobiles such as trucks, buses, motors, scooters, fire engines, ambulances etc, factories, industries, trains, aeroplanes and necessary noise producers such as horns, sirens, loud speakers, musical instruments, TV, radio, transistors, shouting, barking of dogs etc. Man made noise also includes social gatherings, marriages and birthday functions etc.

An ever increasing number of common noise sources are being put into use daily. According to Odum[13], such noise increases with the complexity and information content of systems of all kinds. The term noise is also used in electronics and communication science to refer to perturbations that interfere with man's communications Broadly speaking, noise may be described as

a) Industrial Noise

b) Transport Noise

c) Neighbourhood Noise

a) Industrial Noise

Noise pollution or high intensity sound is caused by many machines, man has invented during his technological advancement. Thus, there exists a long list of sources of noise pollution including different machines of numerous factories, industries and mills. Industrial noise, particularly from mechanical saws and pneumatic drill is unbearable and is a nuisance to public.

b) Transport Noise:-

The noise comes from transport is mainly road traffic noise, rail traffic noise and aircraft noise. The number of road vehicles like motors, scooters, cars, motorcycles, buses trucks and particularly the diesel engine vehicles has increased enormously in recent years. That is why, this form of pollution is gaining importance, especially in large and over crowded towns and cites.

Aircraft noise is causing much more discomfort that from road transport noise. Lager and faster jet aircrafts have been built over the years. The air-traffic has now been increased to such an extent that nobody likes a new airfield in his neighborhood. Loud noise produced by high speed jet aircrafts is not only disturbing human communication comfort and health but can also damage hearing permanently.

c) Neighbourhood Noise

This type of noise includes disturbance from house hold agents and community. Common noise makers are musical instruments. T.V., VCR, Radio, Transistors, Washing Machines, Vacuum Cleaners, Fans, Mixers, Coolers, Air Conditioners, and Loud Speakers etc. ever since, the industrial revolution noise in environment has been doubling every ten years.

It would not be a miss to say that, the Indians are religious minded and their every occasion, function and sentiment is celebrated in a noisy manner. Thus, the variety of sources of noise (e.g. loud speakers at place of worship or marriage and birthday parties etc.) may cause disturbances and annoyance to the public.

4.1.4 NOISE AND HEALTH

The effects of noise on health are numerous. It can affect central nervous system, cause nausea, vomiting, deafness, loss of appetite, loss of sleep and cardiac failure. A person exposed to noise of 90 dB (A) would loose hearing within 30 years with 40 hr/week. A momentary loud thus called impulse causes more damage than continuous noise. Industrial noise affects person inefficiency of working.

4.1.5 UNITS OF SOUND

Generally the sound level is measured in two scales, namely μpa or pascal scale and dB or decibel scale. Approximately 0 dB = 20 μpa sound pressure (that is 700 μpa = 70 dB SPL)

4.2 LITERATURE REVIEW

Singh[26] *et al* (1986) studied the noise pollution in a sugar factory in western Utter Pradesh and the sound levels were observed to be within 80 dB(A) to 105 dB(A). Attarchand (1989) reported that noise level of about 75 dB(A) has been recorded around Jaslok. Nanavati Sion and Looper Hospitals of Mumbai and during night time, it reaches 86 dB(A), When the aircraft off or lands. Ramalingeswara Rao and Seshagiri Rao[18] (1990) carried out noise pollution survey in the City of Visakhapatanam in the year 1986 and the same measurements are repeated in 1987 after a gap of one year to study how the noise level parameters are changing. The Leq, Lnp, TNI and NC are measured hourly for a period of 12 hr and the mean Leq value and these values well above the tolerable limits. Yagnarayana and Ramalingeswara Rao[29] (1994) studied the ambient noise levels at 11 (eleven) traffic junctions are Ramagundam area and the Leq value was found in the range of 64 to 75 dB (A) during day time. Bansal[2] (1996) studied the noise level in the sensitive areas of Bhopal was in the range of 32 to 78 dB(A) during day time while during night time it was in the range of 30 to 60 dB (A). Ambient noise level survey was carried out in the Pondicherry Town (Yogamoorthi and Beena[30] – 1996) at 42 sports in four categories of zones, Viz, Commercial zone, traffic signal points, silent zone and special zone (central bus stand). The noise level in the commercial zone ranged between 60 to 65 dB (A) but at certain times when trucks used air horns the noise level increased up to 70 to 75 dB(A). The noise level in the traffic signal points and special zone ranged between 70 to 80 dB(A) and 70 to 100 dB(A) respectively where as in the silent zone exceeds the limit.

The study conducted by Shastri[24] *et al* (1996) in Mumbai, Delhi, Kolkata and Madras are among the noisiest cities in the world. The normal noise level of Mumbai was found to be 90 dB(A) and Jaipur noise level in Industrial areas ranged from 64 to 80 dB (A). In Madras, the highest noise level near Anna Statue Area was reported to be 117 dB (A) during day time. Pandya and Verma[14] (1997) studied the noise levels in some residential, commercial and sensitive areas in proximity of major traffic intersections and found the L_{eq} value in day time is 58 to 75 dB (A) where as in night time is 48 to 66 dB(A). The study conducted by Ravichandran[19] *et al* (1997) in Tiruchirapalli City reveals that, non of the areas had noise levels less than 45 dB (A). Residential areas, silence zone and commercial places, all exceeds the limit prescribed by the Central Pollution Control Board. The various factors which contribute to noise pollution are increasing population, urbanization, industrialization technological change and the usual relegation of environmental considerations to a position of secondary importance relative to economics. Koijam[7] *et al* (1998) studied the noise levels in selected urban areas of Imphal valley and found 72 to 77 dB (A) in morning 71 to 77 dB(A) in after noon and 60 to 68 dB(A) in night. The observed noise levels were more than the standard permissible limit. Joshi[6] (1998) reported that ambient noise levels at twenty five locations of Indore (M.P) five each belonging to industrial, residential, commercial, silence zones and mixed categories and noise levels at most of the locations exceeded the corresponding standards during day time where as the night time values were mostly within prescribed limits at most of the places. Ravichadran[21] *et al* (1998) studied the status of noise pollution in Hosur (Timilnadu) and found that no sampling station has noise level below 45 dB (A) both during day and night time. Noise levels in silence zones, like hospitals and educational institutions exceeded the limit to 50 dB (A) in day and 45 dB(A) in night. In some important commercial areas, the noise levels were more than 100 dB (A) during day and night time. Singh (2000) et al reported that none of the municipal area of Dhanbad, the noise levels were less than 45 dB (A), even in the silence zones, noise levels were found to exceed the limit of 55 dB(A) in night hours also. Ravichandran[21] *et al* (2000) studied the noise pollution level in Pudukkottai (Tamilnadu) at selected places (silence zones, residential zone and commercial zone) and minimum, maximum, L_{eq}, L_{10}, L_{50} and L_{90} noise levels were computed. None of the places recorded, noise levels within the prescribed limits set by Central Pollution Control Board. Chakraborty[4] *et al* (2002) studied the traffic noise level at twenty four pre selected road transaction of Calcutta Metropolis during 1993-94. The L_{eq} noise level varies from minimum 80.3 dB(A) to maximum 92.1 dB(A). Kumari[10] *et al* (2003) studied the noise levels at ten major hospitals in the Town of Hisar and found that, the ambient noise levels around all the hospitals are beyond the standards prescribed by Central Pollution Control Board, India. The L_{eq} level varies from 71.19 to 61.92 dB (A)

4.3 WORK DONE BY AUTHOR

The study was conducted during the period February – 1995 to August – 1996. Literature survey shows that, no systematic, extensive studies have been conducted on noise pollution in Bondamunda area. The survey timings in various areas were so chosen as to cover the periods of lowest and highest noise levels, which are given in the various tables in subsequent pages.

The measurement of noise levels were conducted with the help of “Precision Sound Level Meter – 2232” manufactured by the firm Bruel and Kajer of Denmark and “Precision Sound Level Meter – 2021”. It is an easy to use, precision class instrument with digital display, measuring maximum RMS (Root Mean Square) sound pressure level in dB (A) (“A” weighted in decibel). This type of instrument used for present survey has built in “A” weighting network and “Fast” and “Slow” detector characteristics. During each hourly interval sound pressure level (SPL) values has been measured for a period of one minute. From the measured value, the parameters L_{10}, $L_{50,}$ L_{90}, L_{eq}, $L_{np,}$ and TNI were computed for that hour. It is calibrated acoustically using on external reference source, which is placed over the microphone.

Measurement of noise from 34 dB (A) to 130 dB(A) can be carried out with this battery operated instrument.

4.4. METHODOLOGY

The parameter universally used in discussion of noise pollution of the environment is L_{eq}, the equivalent continuous noise level expressed in dB(A) which is the average rate of which energy is received by the human ear during the period monitored. This parameter can be obtained by a direct objective measurement with an integrating type sound level meter or can be computed from a sample recording of the time variation of the noise level during that period. The L_{eq} can be estimated by assuming as Gaussion distribution of noise levels using the empirical equation (Kudesia and Tiwari[7] 1993-94)

$$L_{eq} = ½ (L_{10} + L_{90}) + \frac{1}{57} (L_{10} – L_{90})^2 \text{ ----------------------------- } (1)$$

Where L_{10} and L_{90} respectively indicates the level exceeding for 10% and 90% of the time in a record of a noise level in a given interval, another parameter used is the noise.

Pollution level L_{np}, which can be computed from the time varying noise level using the relation (Patrick[17] 1977).

$$L_{np} = L_{50} + (L_{10} + L_{90})^2 \diagup_{60} + (L_{10} – L_{90}) \text{ --------------------------- } (2)$$

Where $L_{10,}$ L_{50}, and L_{90} respectively indicates the level exceeding for 10%, 50% and 90% of the time in a record of a noise level in a given interval, L_{np} is also expressed in units of dB(A).

While L_{eq} level gives the total energy received by the ear and hence an indicator of the physiological disturbance to the hearing mechanism, L_{np} is also takes into account the variations in the sound signal and hence a better indicator of the pollution in the environment for physiological and psychological disturbance of human system. Traffic Noise Index (TNI) is another parameter which indicates the degree of orderliness/ disorderliness in a traffic flow. This is also expressed in dB (A) and can be computed using the relation (Patrick[17] 1977)

$TNI = L_{90} + 4 (L_{10} - L_{90}) - 30$ ------------------------------------ (3)

4.5 RESULTS AND DISCUSSION

The complete results (various parameters) on the noise levels in residential areas, traffic points, public place, bank, etc are given in various tables in subsequent pages. For better understanding, noise levels in each area can be explained as follows.

RESIDENTIAL AREAS

The parameters L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI were calculated using equations 1,2 and 3 for sector – A, Sector – B, Sector – C, Sector – D, Sector – E,. Diesel Colony, Tilkanagar, Dumerta, Gundichapalli and R. S. Colony are given in **Table 4.1** to **4.10** for day time and night time. The average noise level for the ten locations of the computed parameters for Bondamunda are given in **Table – 4.11**. The ambient air quality standards in respect of noise (Central Board for Pollution Control Standards for Noise) are given in **Table 4.12. Fig. 4.1** to **4.10** shows are the parameters like L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI from morning 9.00 AM to night 2.00 AM. **Fig. 4.11** and **4.12** shows the average ambient noise level at Bondamunda for ten locations as monitored during day time and night time respectively.

The L_{10} or 10 percentile exceeding level is the level of sound, which is exceeding 10% of the total time of measurement at residential areas were varying between 52.6 to 75.6 dB(A) in day time and 43.5 to 64.7 dB(A) in night time. The maximum L_{10} values 75.6 dB(A) and 64.7 dB(A) were observed at Tilkanagar between 5.00 PM to 6.00 PM and 9.00 PM to 10.00 PM respectively. The minimum value 52.6 dB(A) and 43.5 dB(A) were recorded at Dumerta between 1.00 PM to 2.00 PM in day time and at sector – C and R. S. colony between 1.00 AM to 2.00 AM in night time respectively. The L_{50} or 50 percentile exceeding level is the level of sound, which is exceeding 50 % of the total time of measurement were varying between 45.6 to 68.4 dB(A) in day time and 42.4 to 60.2 dB(A) in night time. The maximum 68.4 dB(A) and 60.2 dB(A) were observed at Tilkanagar between 5.00 PM. to 6.00 PM. in day time and 9.00 PM. to 10.00 PM in night time respectively. The minimum values of 45.6 dB (A) and 42.4 dB (A) were observed at Sector – B between 2.00 PM to 3.00 PM and R. S. colony between 1.00 AM to 2.00 AM respectively. L_{90} or 90 percentile exceeding level is the level of sound, which is exceeding 90% of the total time of measurement were 42.1 to 63.8 dB(A) in day time and 41.3 to 50.8 dB(A) in night time. The maximum values 63.8 dB(A) and 50.8 dB(A) were observed at Tilkanagar between 5.00 PM. to 6.00 PM in day time and 9.00 PM. to 10.00 PM in night time respectively. The minimum values were observed at Dumerta between 1.00 PM. to 2.00 PM. in day time and 1.00 AM. to 2.00 AM in night time. The L_{eq} is the equivalent continuous noise level measured for each individual hour. The maximum and minimum noise level of each individual hour were observed varying between 46.15 to 72.14 dB(A) in day time and 42.54 to 61.75 dB(A) in night time. The maximum value 72.14 dB(A) and 61.75 dB(A) were recorded at Tilkanagar during 5.00 PM. to 6.00 PM in day time and 9.00 PM to 10.00 PM in night time respectively. The minimum values were observed at sector – B between 2.00 PM to 3.00 PM in day time and Dumerta between 1.00 AM to 2.00 AM in night time. L_{np} is the noise pollution level, which indicates in this area. The L_{np} for each individual hour were varying between 51.72 to 81.52 dB(A) during day time and 44.03 to 69.64 dB(A) in night time. The maximum values were observed at Tilkanagar between 5.00 PM to 6.00 PM in day time and 9.00 PM to 10.00 PM in night time. The minimum values were observed at sector – B between 2.00 PM to 3.00 PM and Sector – C between 1.00 AM. to 2.00 AM.

From the above, it is concluded that, the maximum value of L_{10}, L_{50}, L_{90}, L_{eq} and L_{np} were observed at Tilkanagar area both day time as well as night time, because, that area is near by Industrial area. The L_{10} and L_{90} were minimum at Dumerta during 1.00 PM to 2.00 PM. The minimum value of $L_{50,}$ L_{eq} and L_{np} were observed at sector – B between 2.00 PM to 3.00 PM during day time. The minimum value L_{90} and L_{eq} were observed at Dumerta during 1.00 AM to 2.00 AM, L_{10} and L_{50} were minimum at R. S. Colony during 1.00 AM. to 2.00 AM. As per, the ambient air quality standards in respect of noise, the noise level (L_{eq}) for residential area should be 55 dB(A) in day time and 45 dB(A) in night time. The average noise level (L_{eq}) of all the residential locations of Bondamunda exceeds the prescribed noise standards during the day time as well as night time.

COMMERCIAL AREAS

The parameters L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI were calculated using equations 1,2 and 3 for general post office, Railway station, Bank and Local market are given in **Table 4.13** to **4.16**. **Fig. 4.13** to **4.16** should all the parameters like L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI from morning 8.00 AM. to evening 5.00 PM.

The L_{10} or 10 percentile exceeding level is the level of sound, which is exceeding 10% of the total time of measurement at commercial areas were varying between 103.5 to 62.6 dB (A). The maximum L_{10} value was observed at Railway station between 11.00 AM to 12.00 Noon. The minimum value was recorded at post office during 4.00 PM to 5.00 PM. L_{50} or 50 percentile exceeding level is the level of sound, which is exceeding 50% of the total time of measurement, was varying between 95.4 to 53.8 dB(A). The maximum value was observed at Railway station between 11.00 AM. to 12.00 Noon. The minimum value of 53.8 dB(A) was observed at post office area during 4.00 PM to 5.00 PM. L_{90} or 90 percentile exceeding level is the level of sound, which is exceeding 90% of the total time of measurement was varying between 83.1 to 48.1 dB(A). The maximum value was observed at Railway station area between 11.00 AM to 12.00 Noon. The minimum value of 48.1 dB(A) was observed at post office area between 4.00 PM to 5.00PM. The L_{eq} is the equivalent continuous noise level measured for each individual hour. The maximum and minimum noise level of each individual hour was varying between 100.6 to 59.03 dB(A). The minimum value 59.03 dB(A) was recorded at post office during 4.00 PM to 5.00 PM and maximum value 100.6 dB(A) at Railway station area between 11.00 AM to 12.00 Noon. As per ambient air quality standard in respect of noise (Table 4.12) for commercial areas in day time is 65 dB (A). The noise level (L_{eq}) of Railway station and local market exceeds the limit between 8.00 AM to 5.00 PM but the bank and post office, the noise level exceeds, when the busy transaction hour between 10.00 AM to 2.00 PM. The L_{np} for each individual hour were varying between 122.7 to 71.8 dB (A). The minimum value was observed at the General post office that is 4.00 PM to 5.00 PM. The maximum value 122.7 dB (A) was observed at Railway station during 11.00 AM to 12.00 Noon. TNI is the traffic noise index that causes annoyance due to vehicular traffic. The TNI values observed at commercial areas were varying between 134.7 to 75.6 dB (A). The maximum TNI was observed at Railway station during 11.00 AM to 12.00 Noon the minimum value 75.6 dB (A) was observed at post office area during 2.00 PM to 3.00 PM.

INDUSTRIAL AREA

The noise parameters were calculated using equations 1,2 and 3 for locoshed (Electric and Diesel) and Marshalling yard of Railway are given in **Table 4.17** and **4.18**. **Fig. 4.17** and **4.18** shows all the parameters, like L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI from morning 8.00 AM to evening 5.00 PM.

The L_{10} or 10 percentile exceeding level is the level of sound, which is exceeding 10% of the total time measurement was varying between 101.6 to 70.1 dB (A). The parameter L_{50} or 50 percentile was varying between 90.6 to 61.3 dB (A). L_{90} or 90 percentile was varying between maximum 84.0 dB (A) to minimum 53.8 dB (A). The noise level (L_{eq}) was varying between maximum 99.64 to 66.61 dB (A). The L_{np} for each individual hour were varying between 118.27 to 81.18 dB (A), TNI or Traffic Noise Index value was varying between maximum 139.1 to 85.0 dB (A).

The maximum value L_{10}, L_{90} and TNI were observed between 2.00 PM to 3.00 PM, 12.00 Noon to 1.00 PM and 3.00 PM to 4.00 PM respectively where as the maximum value L_{50}, L_{eq} and L_{np} were observed between 11.00 AM to 12.00 Noon at locoshed location. The minimum value of L_{10}, L_{50}, L_{90}, and L_{eq} were observed between 8.00 am to 9.00 AM where as the minimum value of $L_{np \text{ and}}$ TNI were observed between 3.00 PM to 4.00 PM at Marshalling yard.

SILENCE ZONE

The noise parameters were calculated using equations 1,2, and 3 for Hospital and College are given in **Table 4.19** and **4.20**. **Fig.1.19** and **4.20** shows all the parameters like L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI form morning 8.00 to evening 5.00 PM L_{10} or 10 percentile was varying between maximum 79.6 to minimum 60.1 dB(A). L_{50} or 50 percentile was varying between maximum 70.4 to minimum 54.3 dB (A). L_{90} or 90 percentile was varying between maximum 64.1 to minimum 48.2 dB (A). The noise level L_{eq} was varying between maximum 76.46) to minimum 56.63 dB (A). The L_{np} for each individual hour were varying between maximum 92.59 to minimum 68.56 dB (A). TNI or Traffic Noise Index value was varying between maximum 107.3 to minimum 65.8 dB (A).

The maximum value of L_{10}, L_{50} and L_{90} were observed between 1.00 PM to 2.00 PM, where as the maximum value of L_{10}, $L_{eq,}$ and TNI were observed between 11.00 AM. to 12.00 Noon at College. The maximum value of L_{np} was obtained between 10.00 AM to 11.00 AM at College. The minimum value of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI were observed between 1.00 PM to 2.00 PM at Hospital. As per ambient air quality standard in respect of noise (**Table – 4.12**) for silence zone in day time should be 50.0 dB (A) but the limit is exceeded between 8.00 AM to 5.00 PM at the Hospital and College.

TRAFFIC POINT

The hourly values of the parameters L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI for February – 1995 August – 1995, February – 1996 and August – 1996 are given in **Table 4.21**, **4.22**, **4.23**, and **4.24** respectively.

The location studied falls under the residential cum commercial category. From **Fig. 4.23** and **4.24** shows that, the L_{eq} value increases in the morning hours due to morning school near locality and general shift duty (8.00 AM to 5.00 PM) for the two years. L_{np} value also follows the same trends with a peak around 10.00 AM. This is because of the 10.00 O' clock, office rush which makes the vehicle drivers to speed up and blow horn, which naturally shoots the L_{np} level as well as TNI, L_{eq}, L_{np} and TNI has again exhibited a minor peak around 2.00 pm. This might be due to the office rush for the afternoon session and stating of B – shift and closure of A- shift duty. Around 4.00 PM L_{eq}, L_{np} and TNI show slight dip presumably due to less traffic. After 5.00 PM the traffic starts building up till 8.00 PM. This is probably due to presence of popular shopping center in the area. After 9.00 PM the value starts continuously falling reaching to a minimum. **Fig. 4.21** and **4.22** indicates that, there are peaks around 10.00 AM, 2.00 PM and 8.00 PM in all the values of L_{10} L_{50} and L_{90} and dip around 4.00 PM while L_{10} represent the peak in the noise signal, L_{90} represents the background and L_{50} represents the mean noise level. The virtual constancy of the value of L_{eq} , L_{np} and TNI from **Fig. 4.23** and **4.24** and L_{10} L_{50} and L_{90} form **Fig. 4.21** and **4.22** indicates that, the change of these parameters over a period of one and half year is negligible.

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Table 4.1 Hourly Computed Noise Parameters for Sector –A

Day Time	Parameters Measured in dB (A)					
	L_{10}	L_{50}	L_{90}	L_{eq}	L_{nP}	TNI
9.00 – 10.00	66.3	59.7	56.5	63.08	71.1	65.7
10.00 – 11.00	67.5	60.8	58.1	64.35	71.6	65.7
11.00 – 12.00	67.1	58.3	55.6	63.67	72.0	71.6
12.00 – 1.00	65.7	57.0	54.9	62.34	69.74	68.1
1.00 – 2.00	67.2	57.9	55.1	63.71	72.44	73.5
2.00 – 3.00	64.3	58.1	54.8	61.13	69.1	62.8
3.00 – 4.00	61.4	56.3	54.9	58.89	63.5	50.9
4.00 – 5.00	63.7	60.4	56.1	60.91	68.96	56.5
5.00 – 6.00	67.7	62.3	56.8	64.33	75.18	70.4
6.00 – 7.00	68.1	61.5	58.4	64.9	72.76	67.2
7.00 – 8.00	68.5	62.8	59.2	65.36	73.54	66.4
8.00 – 9.00	68.3	62.7	58.5	65.8	74.1	67.7
Night Time						
9.00 – 10.00	59.5	55.9	53.4	57.1	62.62	47.48
10.00 – 11.00	58.3	53.5	50.7	55.1	62.06	51.1
11.00 – 12.00	54.3	51.1	49.3	52.23	56.51	39.3
12.00 – 1.00	55.7	50.5	48.6	53.03	58.44	47.0
1.00 – 2.00	53.9	50.5	48.2	51.62	56.74	39.8

Table 4.2 Hourly Computed Noise Parameters for Sector –B

Day Time	Parameters Measured in dB (A)					
	L_{10}	L_{50}	L_{90}	L_{eq}	L_{nP}	TNI
9.00 – 10.00	60.7	55.4	51.4	57.98	63.58	52.6
10.00 – 11.00	64.3	60.9	56.1	61.37	70.22	58.9
11.00 – 12.00	61.5	54.0	50.6	58.13	66.88	64.2
12.00 – 1.00	56.7	50.1	45.4	53.29	63.52	60.6
1.00 – 2.00	51.2	46.3	43.7	48.43	54.73	43.7
2.00 – 3.00	48.4	45.6	42.8	46.15	51.72	35.2
3.00 – 4.00	54.1	49.3	45.9	51.17	58.62	48.7
4.00 – 5.00	57.2	51.5	48.0	54.08	62.1	54.8
5.00 – 6.00	62.7	57.4	52.1	59.37	69.87	64.5
6.00 – 7.00	60.3	55.5	51.7	57.39	65.33	56.1
7.00 – 8.00	62.4	57.1	52.4	59.15	68.76	62.4
8.00 – 9.00	58.7	55.4	49.6	55.6	65.88	56.0
Night Time						
9.00 – 10.00	54.1	51.9	48.3	51.79	58.26	41.5
10.00 – 11.00	52.5	49.0	45.4	49.83	56.94	43.8
11.00 – 12.00	47.4	45.3	42.6	45.4	50.48	31.8
12.00 – 1.00	46.8	44.1	42.3	44.9	48.93	30.3
1.00 – 2.00	45.1	43.8	42.5	43.91	46.51	22.9

Table 4.3 Hourly Computed Noise Parameters for Sector –C

Day Time	Parameters Measured in dB (A)					
	L_{10}	L_{50}	L_{90}	L_{eq}	L_{nP}	TNI
9.00 – 10.00	62.5	56.1	50.2	59.0	72.92	69.4
10.00 – 11.00	68.1	61.9	58.6	64.93	72.9	66.6
11.00 – 12.00	62.8	58.4	53.5	59.66	69.14	60.7
12.00 – 1.00	61.4	56.6	54.7	58.83	64.04	51.5
1.00 – 2.00	58.3	54.8	51.0	55.58	62.98	50.2
2.00 – 3.00	52.1	48.6	44.8	49.41	56.78	44.0
3.00 – 4.00	51.6	48.4	46.5	49.5	53.93	36.9
4.00 – 5.00	62.3	51.1	49.7	58.78	66.34	70.1
5.00 – 6.00	65.5	60.3	57.8	62.69	68.98	58.6
6.00 – 7.00	63.1	58.6	55.4	60.29	67.28	56.2
7.00 – 8.00	64.5	55.0	52.7	61.04	68.62	69.9
8.00 – 9.00	57.1	53.4	51.2	54.76	59.88	44.8
Night Time						
9.00 – 10.00	55.6	52.1	49.6	53.23	58.7	43.6
10.00 – 11.00	52.5	48.4	45.1	49.76	56.71	44.7
11.00 – 12.00	46.1	44.2	43.4	44.87	47.01	24.2
12.00 – 1.00	44.8	43.6	42.7	43.82	45.77	21.1
1.00 – 2.00	43.5	42.6	42.1	42.86	44.03	17.7

Table 4.4 Hourly Computed Noise Parameters for Sector –D

Day Time	Parameters Measured in dB (A)					
	L_{10}	L_{50}	L_{90}	L_{eq}	L_{nP}	TNI
9.00 – 10.00	68.1	60.7	56.8	64.69	74.12	72.0
10.00 – 11.00	70.4	65.9	62.5	67.54	74.84	64.1
11.00 – 12.00	66.0	60.8	57.3	62.97	70.76	62.1
12.00 – 1.00	64.3	59.7	55.2	61.2	70.18	61.6
1.00 – 2.00	62.1	58.5	56.8	59.94	64.26	48.0
2.00 – 3.00	65.4	59.1	55.8	62.21	70.23	64.2
3.00 – 4.00	65.1	60.3	55.9	61.98	70.9	62.7
4.00 – 5.00	71.4	64.5	60.2	68.0	77.79	75.0
5.00 – 6.00	72.5	65.8	63.7	69.45	75.89	68.9
6.00 – 7.00	70.6	64.3	60.1	67.28	76.63	72.1
7.00 – 8.00	65.4	61.0	58.8	62.86	68.32	55.2
8.00 – 9.00	63.7	59.1	55.6	60.8	68.29	58.0
Night Time						
9.00 – 10.00	62.7	57.3	52.5	59.42	69.23	63.3
10.00 – 11.00	58.6	53.9	50.8	55.76	62.71	52.0
11.00 – 12.00	56.5	53.3	50.1	54.01	60.38	45.7
12.00 – 1.00	54.5	52.7	49.8	52.53	57.76	38.6
1.00 – 2.00	52.1	50.6	49.5	50.91	53.31	29.9

Table 4.5 Hourly Computed Noise Parameters for Sector –E

Day Time	Parameters Measured in dB (A)					
	L_{10}	L_{50}	L_{90}	L_{eq}	L_{nP}	TNI
9.00 – 10.00	58.4	52.5	46.7	54.95	66.53	75.2
10.00 – 11.00	62.6	55.0	50.1	59.09	70.1	70.1
11.00 – 12.00	60.3	52.8	48.4	56.83	67.66	66.0
12.00 – 1.00	58.7	51.6	49.3	55.55	62.47	56.9
1.00 – 2.00	56.5	50.4	45.1	53.08	63.96	60.7
2.00 – 3.00	54.1	49.3	43.6	50.78	61.63	55.6
3.00 – 4.00	53.8	48.8	44.7	50.70	59.28	51.1
4.00 – 5.00	57.4	51.5	46.9	54.08	63.83	58.9
5.00 – 6.00	63.4	56.3	52.6	60.04	68.64	65.8
6.00 – 7.00	60.3	55.4	51.8	57.31	65.1	55.8
7.00 – 8.00	58.1	54.3	48.7	54.95	65.17	56.3
8.00 – 9.00	56.5	50.8	44.5	53.05	64.78	61.6
Night Time						
9.00 – 10.00	58.4	51.6	46.3	54.91	66.14	64.7
10.00 – 11.00	53.3	48.5	44.8	50.31	58.2	48.8
11.00 – 12.00	48.6	44.3	42.9	46.32	50.54	35.7
12.00 – 1.00	46.5	44.8	43.1	45.0	48.39	26.7
1.00 – 2.00	45.3	43.6	42.7	44.11	46.31	23.1

Table 4.6 Hourly Computed Noise Parameters for Diesel Colony

Day Time	Parameters Measured in dB (A)					
	L_{10}	L_{50}	L_{90}	L_{eq}	L_{nP}	TNI
9.00 – 10.00	59.4	52.6	47.2	55.91	67.28	66.0
10.00 – 11.00	62.5	53.1	48.3	58.93	70.66	75.1
11.00 – 12.00	65.4	56.0	52.6	61.87	71.53	73.8
12.00 – 1.00	56.3	51.2	45.7	52.97	63.67	58.1
1.00 – 2.00	55.1	50.8	45.8	51.96	61.54	53.0
2.00 – 3.00	58.6	52.3	46.5	55.11	66.84	64.9
3.00 – 4.00	61.5	54.8	50.4	58.11	67.95	64.8
4.00 – 5.00	63.7	56.1	52.3	60.20	69.66	67.9
5.00 – 6.00	65.4	60.5	56.1	62.26	71.24	63.3
6.00 – 7.00	67.2	63.5	60.3	64.58	71.19	57.9
7.00 – 8.00	65.1	60.3	55.8	61.96	71.04	63.0
8.00 – 9.00	62.5	55.8	50.6	59.03	70.06	68.2
Night Time						
9.00 – 10.00	60.2	56.3	51.5	57.17	66.26	56.3
10.00 – 11.00	58.9	54.6	50.1	55.85	64.69	55.3
11.00 – 12.00	54.5	52.0	48.6	52.16	58.48	42.2
12.00 – 1.00	50.4	48.7	46.3	48.64	53.08	32.7
1.00 – 2.00	46.8	46.1	45.4	46.13	47.53	21.0

Table 4.7 Hourly Computed Noise Parameters for Tilkanagar

Day Time	Parameters Measured in dB (A)					
	L_{10}	L_{50}	L_{90}	L_{eq}	L_{nP}	TNI
9.00 – 10.00	69.5	62.1	57.8	66.05	76.08	86.3
10.00 – 11.00	71.3	64.8	59.5	67.84	78.92	88.5
11.00 – 12.00	72.5	66.7	60.4	69.01	81.24	90.9
12.00 – 1.00	69.7	65.0	58.3	66.28	78.56	85.3
1.00 – 2.00	68.9	64.3	61.5	66.16	72.61	68.5
2.00 – 3.00	74.1	67.8	62.6	70.64	81.92	91.3
3.00 – 4.00	72.6	64.9	58.4	69.03	82.46	99.4
4.00 – 5.00	65.3	62.6	58.1	62.6	70.66	64.1
5.00 – 6.00	75.6	68.4	63.8	72.14	82.52	92.8
6.00 – 7.00	71.5	65.4	60.8	68.15	78.00	84.3
7.00 – 8.00	67.3	64.1	59.5	64.46	72.91	68.5
8.00 – 9.00	66.4	63.5	58.1	63.45	72.94	69.6
Night Time						
9.00 – 10.00	64.7	60.2	56.4	61.75	69.64	67.9
10.00 – 11.00	62.3	58.0	54.5	59.46	66.81	63.5
11.00 – 12.00	60.4	55.7	52.3	57.5	64.89	62.8
12.00 – 1.00	55.3	52.5	51.1	53.61	56.65	40.9
1.00 – 2.00	52.6	51.9	50.8	51.75	53.75	29.8

Table 4.8 Hourly Computed Noise Parameters for Dumerta.

Day Time	Parameters Measured in dB (A)					
	L_{10}	L_{50}	L_{90}	L_{eq}	L_{nP}	TNI
9.00 – 10.00	56.6	51.4	44.8	53.14	65.52	73.8
10.00 – 11.00	58.3	52.0	45.7	54.78	67.24	78.7
11.00 – 12.00	57.4	52.6	48.5	54.33	62.82	63.0
12.00 – 1.00	59.8	52.7	46.3	56.24	69.23	83.8
1.00 – 2.00	52.6	47.0	42.1	49.28	59.33	64.6
2.00 – 3.00	55.7	49.8	44.8	52.33	62.68	69.3
3.00 – 4.00	58.3	51.6	45.7	54.78	66.84	78.7
4.00 – 5.00	63.8	56.9	52.7	60.41	70.05	78.2
5.00 – 6.00	69.7	61.3	55.8	66.13	78.42	95.3
6.00 – 7.00	63.4	57.1	51.6	59.94	71.22	80.6
7.00 – 8.00	66.9	59.3	54.8	62.81	73.84	85.3
8.00 – 9.00	64.8	56.7	51.9	61.26	72.37	86.4
Night Time						
9.00 – 10.00	63.5	56.9	51.6	60.03	71.16	81.5
10.00 – 11.00	52.3	48.1	42.8	49.13	59.1	60.3
11.00 – 12.00	48.7	45.4	42.5	46.27	52.24	43.5
12.00 – 1.00	45.1	43.0	41.8	43.69	46.48	28.3
1.00 – 2.00	43.6	42.5	41.3	42.54	44.89	22.8

Table 4.9 Hourly Computed Noise Parameters for Gundichapalli.

Day Time	Parameters Measured in dB (A)					
	L_{10}	L_{50}	L_{90}	L_{eq}	L_{nP}	TNI
9.00 – 10.00	60.4	55.8	49.7	57.05	68.41	62.5
10.00 – 11.00	63.8	57.3	51.5	60.30	72.12	70.7
11.00 – 12.00	58.4	55.0	50.7	55.59	63.68	51.5
12.00 – 1.00	61.3	56.5	51.2	58.03	68.3	61.6
1.00 – 2.00	64.0	58.4	53.9	60.76	70.2	64.3
2.00 – 3.00	62.7	56.3	50.4	59.2	71.12	69.6
3.00 – 4.00	58.1	55.8	50.8	55.38	63.98	50.0
4.00 – 5.00	56.7	54.3	49.9	54.11	61.87	47.1
5.00 – 6.00	62.4	55.8	51.7	59.05	68.4	64.5
6.00 – 7.00	65.5	59.3	56.9	62.49	69.13	61.3
7.00 – 8.00	66.5	60.1	54.4	63.01	74.64	72.8
8.00 – 9.00	64.8	56.6	49.9	61.24	75.2	79.5
Night Time						
9.00 – 10.00	63.4	56.7	50.1	59.85	72.94	73.3
10.00 – 11.00	56.5	51.8	45.0	53.07	65.2	61.0
11.00 – 12.00	51.2	48.1	44.5	48.63	55.54	41.3
12.00 – 1.00	46.6	44.8	43.8	45.33	48.9	25.0
1.00 – 2.00	45.5	44.6	43.1	44.4	47.1	22.7

Table 4.10 Hourly Computed Noise Parameters for R.S. Colony.

Day Time	Parameters Measured in dB (A)					
	L_{10}	L_{50}	L_{90}	L_{eq}	L_{nP}	TNI
9.00 – 10.00	55.8	50.5	44.7	52.41	63.65	59.1
10.00 – 11.00	62.3	53.4	46.5	58.72	73.36	79.7
11.00 – 12.00	60.5	52.8	48.1	56.99	67.76	80.1
12.00 – 1.00	58.4	52.3	48.6	55.18	63.7	57.8
1.00 – 2.00	56.2	51.9	47.5	53.17	61.86	52.3
2.00 – 3.00	55.4	50.1	44.6	52.04	62.84	57.8
3.00 – 4.00	53.5	47.5	42.7	49.14	60.24	55.9
4.00 – 5.00	57.4	51.3	45.8	53.96	65.14	62.2
5.00 – 6.00	66.7	60.1	54.5	63.21	74.78	73.3
6.00 – 7.00	68.2	61.8	55.4	64.67	77.33	76.6
7.00 – 8.00	65.4	57.3	50.7	61.54	75.6	79.5
8.00 – 9.00	56.8	50.5	43.6	53.25	66.6	66.4
Night Time						
9.00 – 10.00	55.8	50.1	44.9	52.43	62.98	58.5
10.00 – 11.00	47.3	45.4	42.6	45.33	50.46	31.4
11.00 – 12.00	46.5	44.8	42.1	44.63	49.52	29.7
12.00 – 1.00	43.8	42.6	41.8	42.87	44.67	19.8
1.00 – 2.00	43.5	42.4	41.5	42.78	45.28	63.5

Table 4.11 Average Ambient Noise Parameters for Various Locations at Bondamunda.

Locations	Noise levels in dB (A) during day time					
	L_{10}	L_{50}	L_{90}	L_{eq}	L_{nP}	TNI
1	66.31	59.81	56.57	63.2	71.16	65.54
2	58.18	53.2	49.14	55.17	63.43	54.8
3	60.75	55.26	52.17	57.87	65.31	56.57
4	67.8	61.64	58.22	64.07	71.85	63.65
5	58.34	52.39	47.7	55.03	64.92	61.16
6	61.89	55.58	50.96	58.57	68.55	64.06
7	70.39	64.96	59.97	67.15	77.4	82.45
8	60.6	54.03	48.72	57.19	68.3	78.14
9	62.05	56.76	51.75	58.85	68.12	62.95
10	59.71	53.29	47.72	56.21	67.73	66.72
Locations	Noise levels in dB (A) during night time					
1	56.34	52.3	50.04	53.81	59.27	44.93
2	49.18	46.82	44.22	47.16	52.12	34.06
3	48.5	46.18	44.58	46.9	50.44	30.26
4	56.88	53.56	50.54	54.52	60.69	45.9
5	50.42	46.56	43.96	48.13	53.91	39.8
6	54.16	51.54	48.38	51.99	58.00	41.5
7	59.06	55.66	53.08	56.81	62.34	52.98
8	50.64	47.18	44.0	48.32	54.77	47.28
9	52.64	49.2	45.3	50.25	57.93	44.66
10	47.32	45.06	42.58	45.6	50.58	40.58

Table 4.12 Central Board for Pollution Control Standards for Noise

Area	Day dB(A)	Night dB(A)
Silence Zone	50	40
Residential	55	45
Commercial	65	55
Industrial	75	70

Day Time : 6.00 A.M. to 9.00 P.M

Night Time : 9.00 P.M. to 6.00 A.M

- Silence Zone is defined as area upto 100m around such premises as hospitals, educational institutions and courts. The silence zones are to be declared by the competent authority. Use of Vehicles horns, loudspeakers and bursting of cracker shall be banned in these zones.

Table 4.13 Hourly Computed Noise Parameters for Post Office

Time	Parameters Measured in dB(A)					
	L_{10}	L_{50}	L_{90}	Leq	L_{np}	TNI
8.00 AM - 9.00 AM	66.3	58.4	52.1	62.73	75.96	78.9
9.00 AM -10.00 AM	72.3	61.5	56.8	68.76	81.1	88.8
10.00 AM -11.00 AM	75.3	66.7	58.1	71.89	88.8	96.9
11.00 AM - 12.00 Noon	74.3	65.1	60.0	71.24	83.55	87.2
12.00 Noon - 1.00 PM	76.3	66.2	54.7	71.93	95.92	111.9
1.00 PM - 2.00 PM	68.7	60.5	52.4	65.21	81.22	87.6
2.00 PM - 3.00 PM	65.1	56.3	51.6	61.54	72.83	75.6
3.00 PM - 4.00 PM	68.3	57.1	52.9	64.54	76.45	84.5
4.00 PM - 5.00 PM	62.6	53.8	48.1	59.03	71.8	76.1

Table 4.14 Hourly Computed Noise Parameters for Railway Station

Time	Parameters Measured in dB(A)					
	L_{10}	L_{50}	L_{90}	Leq	L_{np}	TNI
8.00 AM - 9.00 AM	79.4	72.3	62.8	75.93	93.49	99.2
9.00 AM - 10.00 AM	86.1	75.8	66.5	83.03	101.8	114.9
10.00 AM - 11.00 AM	82.6	76.4	68.1	79.03	94.4	96.1
11.00 AM - 12.00 Noon	103.5	95.4	83.1	100.6	122.73	134.7
12.00 Noon - 1.00 PM	90.4	82.5	72.0	87.1	106.54	115.6
1.00 PM - 2.00 PM	85.6	76.7	70.1	82.06	96.2	102.1
2.00 PM - 3.00 PM	81.5	72.3	62.9	78.26	96.6	107.3
3.00 PM - 4.00 PM	96.2	83.5	76.4	93.17	109.83	125.6
4.00 PM - 5.00 PM	92.4	80.5	72.6	89.37	106.83	121.8

Table 4.15 Hourly Computed Noise Parameters for Bank

Time	Parameters Measured in dB(A)					
	L_{10}	L_{50}	L_{90}	Leq	L_{np}	TNI
9.00 AM - 10.00 AM	69.5	61.3	56.8	65.97	76.68	77.6
10.00 AM - 11.00 AM	74.8	62.7	56.7	71.49	86.26	99.1
11.00 AM - 12.00 Noon	77.2	65.0	57.9	74.05	90.5	105.1
12.00 Noon - 1.00 PM	78.7	65.8	57.5	75.98	94.49	112.3
1.00 PM - 2.00 PM	76.2	65.1	58.8	72.81	87.54	98.4
2.00 PM - 3.00 PM	69.2	60.3	55.3	65.63	77.42	80.9
3.00 PM - 4.00 PM	68.7	61.5	54.8	65.13	78.64	80.4
4.00 PM - 5.00 PM	65.7	61.4	52.8	62.16	77.07	74.4

Table 4.16 Hourly Computed Noise Parameters for Local Market

Time	Parameters Measured in dB(A)					
	L_{10}	L_{50}	L_{90}	Leq	L_{np}	TNI
9.00 AM - 10.00 AM	70.4	64.7	58.4	66.92	79.1	76.4
10.00 AM - 11.00 AM	75.3	64.1	58.9	71.81	84.98	94.5
11.00 AM - 12.00 Noon	76.5	65.0	59.3	73.09	87.1	98.1
12.00 Noon - 1.00 PM	79.4	66.3	61.8	76.03	89.06	102.2
1.00 PM - 2.00 PM	85.9	74.6	67.1	82.7	99.29	112.3
2.00 PM - 3.00 PM	88.6	75.3	69.0	85.53	101.3	117.4
3.00 PM - 4.00 PM	90.4	80.3	71.6	87.2	104.99	116.8
4.00 PM - 5.00 PM	77.6	65.4	60.3	74.2	87.68	99.5

Table 4.17 Hourly Computed Noise Parameters for Locoshed.

Time	Parameters Measured in dB(A)					
	L_{10}	L_{50}	L_{90}	Leq	L_{np}	TNI
8.00 AM - 9.00 AM	93.5	85.7	79.0	89.93	103.7	107.0
9.00 AM - 10.00 AM	98.4	86.5	79.5	95.15	111.35	125.1
10.00 AM - 11.00 AM	99.2	90.4	83.5	95.67	110.2	116.3
11.00 AM - 12.00 Noon	102.5	90.6	81.9	99.64	118.27	134.3
12.00 Noon - 1.00 PM	99.4	88.7	84.0	95.86	108.05	115.6
1.00 PM - 2.00 PM	92.7	84.3	76.6	89.19	104.72	111.0
2.00 PM - 3.00 PM	95.1	83.6	79.7	91.56	102.95	111.3
3.00 PM - 4.00 PM	101.6	85.4	79.1	99.23	116.33	139.1
4.00 PM - 5.00 PM	90.4	82.7	76.5	86.83	99.82	102.1

Table 4.18 Hourly Computed Noise Parameters for Marshalling Yard.

Time	Parameters Measured in dB(A)					
	L_{10}	L_{50}	L_{90}	Leq	L_{np}	TNI
8.00 AM - 9.00 AM	70.1	61.3	53.8	66.61	82.02	89.0
9.00 AM - 10.00 AM	75.4	64.3	56.1	72.25	89.8	103.3
10.00 AM - 11.00 AM	82.6	72.9	65.5	79.18	94.87	103.9
11.00 AM - 12.00 Noon	94.1	81.6	73.8	91.17	108.76	125.0
12.00 Noon - 1.00 PM	87.4	76.5	71.7	83.87	96.30	104.5
1.00 PM - 2.00 PM	86.7	74.5	68.1	83.46	98.86	111.5
2.00 PM - 3.00 PM	77.3	68.4	60.6	73.84	89.74	97.4
3.00 PM - 4.00 PM	76.1	64.5	62.5	72.5	81.18	85.0
4.00 PM - 5.00 PM	71.3	62.6	54.1	67.74	84.73	92.9

Table 4.19 Hourly Computed Noise Parameters for Hospital

Time	Parameters Measured dB(A)					
	L_{10}	L_{50}	L_{90}	Leq	L_{np}	TNI
8.00 AM - 9.00 AM	76.2	65.4	58.5	72.84	88.32	99.3
9.00 AM - 10.00 AM	74.5	64.0	57.8	71.04	85.34	94.6
10.00 AM - 11.00 AM	72.4	65.3	56.1	68.91	86.02	91.3
11.00 AM - 12.00 Noon	69.1	61.4	53.6	65.66	80.9	85.6
12.00 Noon - 1.00 PM	70.4	60.7	54.3	66.89	81.1	88.7
1.00 PM - 2.00 PM	60.1	54.3	48.2	56.63	68.56	65.8
2.00 PM - 3.00 PM	63.2	55.8	49.6	59.64	72.48	74.0
3.00 PM - 4.00 PM	69.8	56.7	53.6	66.3	77.27	88.4
4.00 PM - 5.00 PM	71.6	58.4	55.2	68.11	79.28	90.8

Table 4.20 Hourly Computed Noise Parameters for College

Time	Parameters Measured dB(A)					
	L_{10}	L_{50}	L_{90}	Leq	L_{np}	TNI
8.00 AM - 9.00 AM	71.4	62.3	54.8	67.93	83.69	91.2
9.00 AM - 10.00 AM	75.3	64.1	56.5	72.1	88.79	101.7
10.00 AM - 11.00 AM	78.4	67.9	59.6	75.2	92.59	104.8
11.00 AM - 12.00 Noon	79.6	66.4	60.4	76.46	91.74	107.3
12.00 Noon - 1.00 PM	76.3	68.4	58.9	72.91	90.84	98.5
1.00 PM - 2.00 PM	79.6	70.4	64.1	76.06	89.9	96.1
2.00 PM - 3.00 PM	78.5	68.3	60.4	75.19	91.86	102.8
3.00 PM - 4.00 PM	76.4	65.8	59.0	73.01	83.00	98.6
4.00 PM - 5.00 PM	70.3	63.3	56.1	66.73	81.36	82.9

Table 4.21 Hourly Computed Noise Parameters for Road Traffic in February-1995.

Day Time	Parameters Measured in dB(A)					
	L_{10}	L_{50}	L_{90}	L_{eq}	L_{nP}	TNI
6.00-7.00	79.5	72.3	64.3	75.95	91.35	95.1
7.00-8.00	81.7	72.2	65.8	78.18	92.31	99.4
8.00-9.00	81.6	71.2	64.4	78.19	93.33	103.2
9.00-10.00	88.6	73.5	68.9	85.58	99.6	117.7
10.00-11.00	84.5	72.1	67.8	81.04	93.45	104.6
11.00-12.00	83.5	73.9	69.2	79.93	91.61	96.4
12.00-1.00	84.8	71.2	68.7	81.29	91.62	103.1
1-00-2.00	88.5	73.6	70.1	85.23	97.64	113.7
2.00-3.00	83.7	70.5	66.8	80.26	92.16	104.4
3.00-4.00	78.4	68.2	62.7	74.87	88.22	95.5
4.00-5.00	80.5	70.8	63.2	77.1	93.08	102.4
5.00-6.00	85.8	72.4	66.5	82.68	97.9	113.7
6.00-7.00	84.2	73.5	67.1	81.78	95.47	105.5
7.00-8.00	88.3	72.7	69.1	84.66	98.04	115.9
8.00-9.00	82.7	72.2	65.8	79.26	93.86	103.4
Night Time						
9.00-10.00	80.4	68.3	64.7	76.87	88.1	97.5
10.00-11.00	72.5	61.1	56.7	68.98	81.06	89.9
11.00-12.00	71.4	60.2	56.7	67.84	78.5	85.5

Table 4.22 Hourly Computed Noise Parameters for Road Traffic in August-1995.

Day Time	Parameters Measured in dB(A)					
	L_{10}	L_{50}	L_{90}	L_{eq}	L_{nP}	TNI
6.00-7.00	78.2	71.5	61.7	74.72	92.53	97.7
7.00-8.00	80.5	72.7	63.5	77.07	94.51	101.5
8.00-9.00	83.9	75.6	67.3	80.43	96.79	103.7
9.00-10.00	89.4	76.2	71.3	86.09	99.76	114.7
10.00-11.00	86.3	75.4	70.6	82.77	95.2	103.4
11.00-12.00	83.5	72.8	68.6	79.94	91.4	98.2
12.00-1.00	82.7	71.5	67.5	79.15	90.55	98.3
1-00-2.00	88.9	74.1	71.2	85.54	99.02	112.0
2.00-3.00	86.5	73.8	71.1	82.95	92.95	102.0
3.00-4.00	81.2	72.3	65.4	76.68	92.26	98.6
4.00-5.00	83.3	73.5	66.8	79.82	94.53	102.8
5.00-6.00	86.5	74.3	68.7	83.15	97.38	109.9
6.00-7.00	84.3	74.5	69.8	80.74	92.5	97.8
7.00-8.00	85.4	75.8	70.1	81.85	95.09	101.3
8.00-9.00	80.1	72.4	65.2	76.54	88.25	94.8
Night Time						
9.00-10.00	79.8	69.3	63.2	76.34	90.49	99.6
10.00-11.00	74.3	66.5	58.7	70.76	86.15	91.1
11.00-12.00	72.4	62.7	56.3	68.89	83.12	90.7

Table 4.23 Hourly Computed Noise Parameters for Road Traffic in February-1996.

Day Time	Parameters Measured in dB(A)					
	L_{10}	L_{50}	L_{90}	L_{eq}	L_{nP}	TNI
6.00-7.00	79.2	65.6	61.7	75.8	88.2	101.7
7.00-8.00	80.6	69.4	63.1	77.12	92.0	103.1
8.00-9.00	81.5	70.2	64.3	78.1	92.3	103.1
9.00-10.00	86.3	72.1	66.4	83.29	98.6	116.0
10.00-11.00	84.2	71.6	65.3	81.0	96.45	110.9
11.00-12.00	83.3	71.4	64.8	80.05	95.6	108.8
12.00-1.00	82.6	72.4	63.8	79.4	97.09	109.0
1-00-2.00	87.9	73.5	66.4	85.25	102.7	122.7
2.00-3.00	85.2	73.06	68.2	81.77	95.41	106.2
3.00-4.00	80.2	71.3	66.8	76.63	88.42	91.9
4.00-5.00	81.5	69.9	65.1	78.0	90.78	100.7
5.00-6.00	88.6	73.5	69.2	85.5	99.17	116.8
6.00-7.00	86.7	72.3	68.5	83.41	96.02	111.3
7.00-8.00	87.4	73.1	68.6	84.2	97.7	113.8
8.00-9.00	86.2	73.8	69.4	82.75	95.3	106.6
Night Time						
9.00-10.00	82.1	70.6	65.4	78.69	91.94	102.2
10.00-11.00	71.6	62.3	56.8	68.04	80.75	86.0
11.00-12.00	70.3	58.5	55.9	66.7	76.35	83.5

Table 4.24 Hourly Computed Noise Parameters for Road Traffic in August-1996.

Day Time	Parameters Measured in dB(A)					
	L_{10}	L_{50}	L_{90}	L_{eq}	L_{nP}	TNI
6.00-7.00	75.7	68.2	57.4	72.42	92.08	100.6
7.00-8.00	78.6	70.5	60.4	75.31	94.22	103.2
8.00-9.00	82.3	74.2	65.8	78.8	95.2	101.8
9.00-10.00	88.6	75.3	69.8	85.4	99.99	115.0
10.00-11.00	86.3	72.5	69.4	82.86	94.16	107.0
11.00-12.00	79.4	68.5	65.2	75.8	86.06	92.0
12.00-1.00	82.6	70.4	68.7	79.0	87.52	94.3
1-00-2.00	87.8	72.1	65.3	85.43	103.03	125.3
2.00-3.00	85.4	73.7	68.1	82.0	95.98	107.3
3.00-4.00	80.2	70.4	66.7	76.64	86.93	90.7
4.00-5.00	84.8	72.5	69.4	81.2	91.85	101.0
5.00-6.00	87.2	74.3	70.6	83.7	95.49	107.0
6.00-7.00	83.8	72.5	69.7	80.23	89.91	96.1
7.00-8.00	88.5	76.6	71.3	85.09	98.93	110.1
8.00-9.00	81.3	71.8	65.6	77.72	91.6	98.4
Night Time						
9.00-10.00	79.3	70.2	61.9	75.91	92.6	101.5
10.00-11.00	76.2	65.5	58.2	72.88	88.9	100.2
11.00-12.00	70.4	59.3	55.8	66.83	77.46	84.2

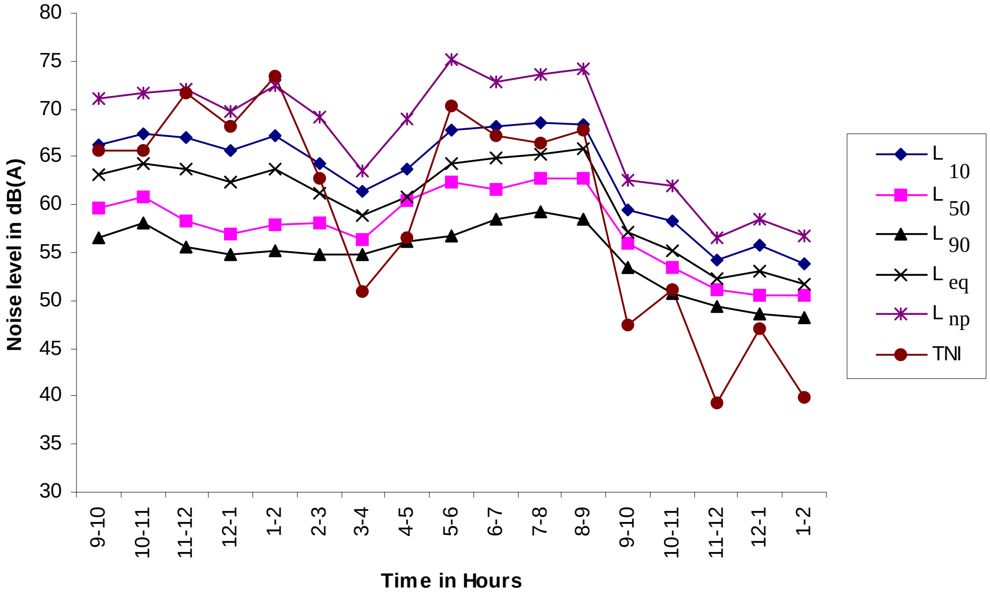

Fig. 4.1 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI for Sector-A

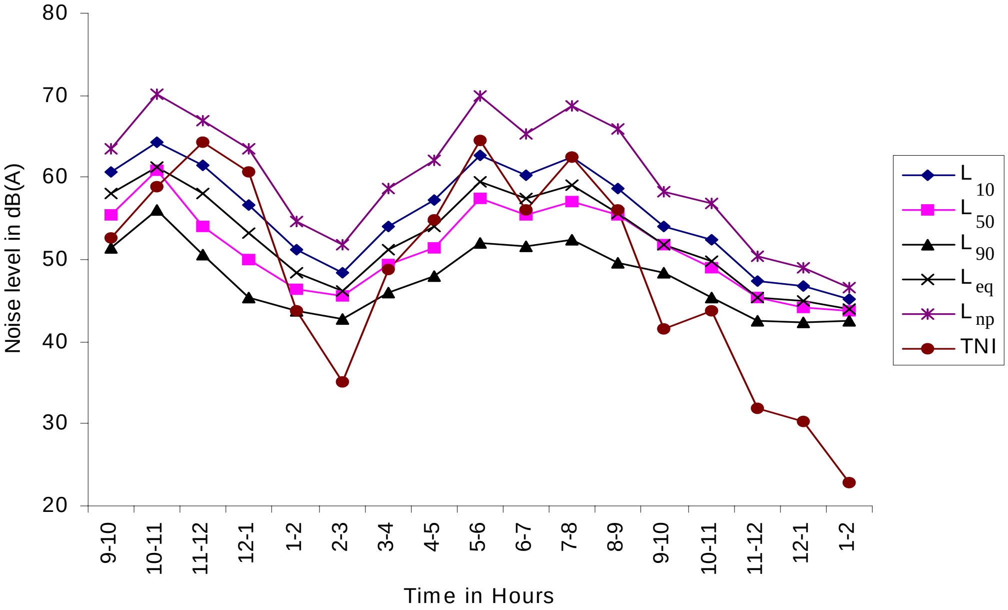

Fig. 4.2 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI for Sector-B

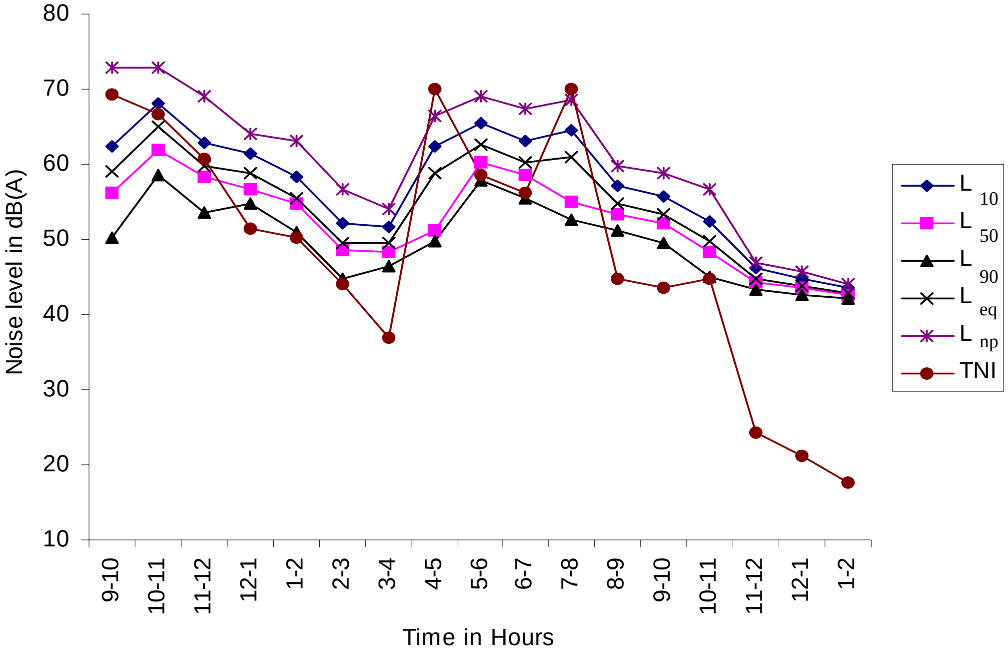

Fig. 4.3 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI for Sector-C

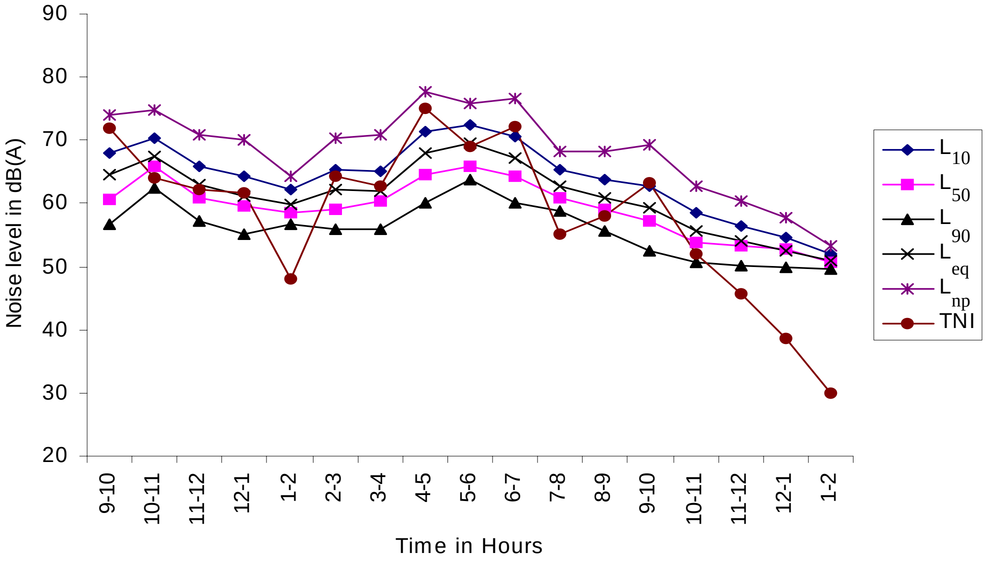

Fig. 4.4 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI for Sector-D

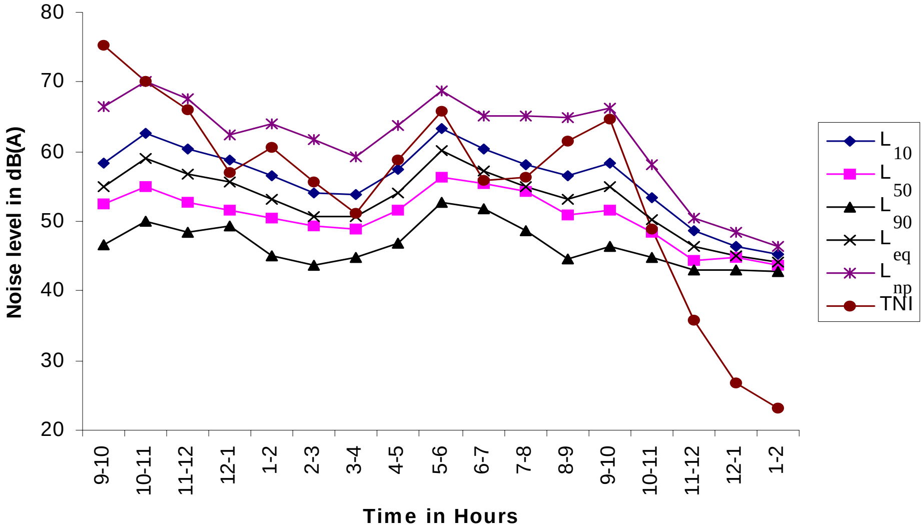

Fig. 4.5 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI for Sector-E

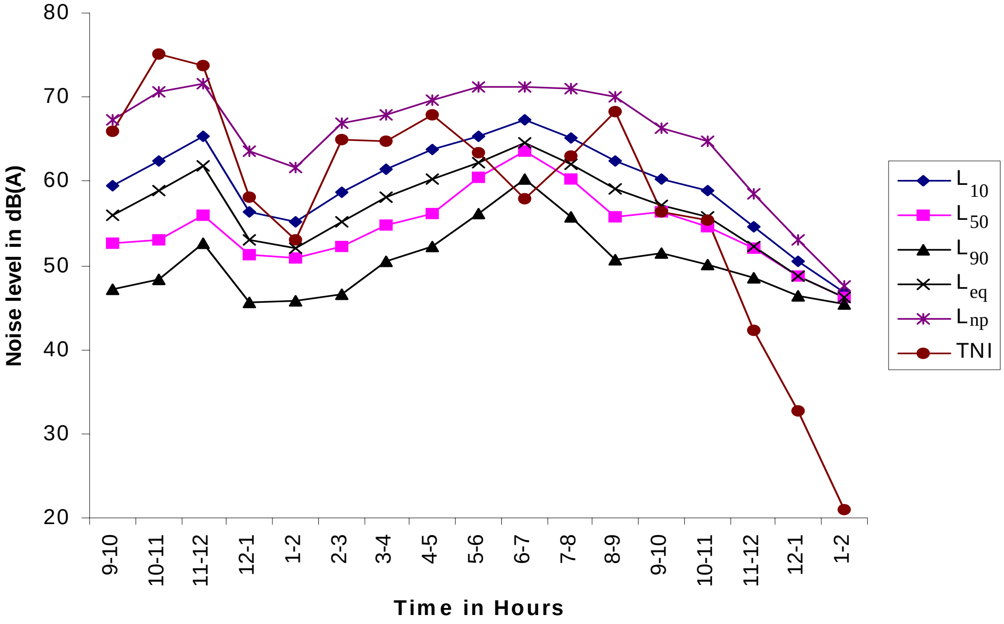

Fig. 4.6 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI for Diesel Colony

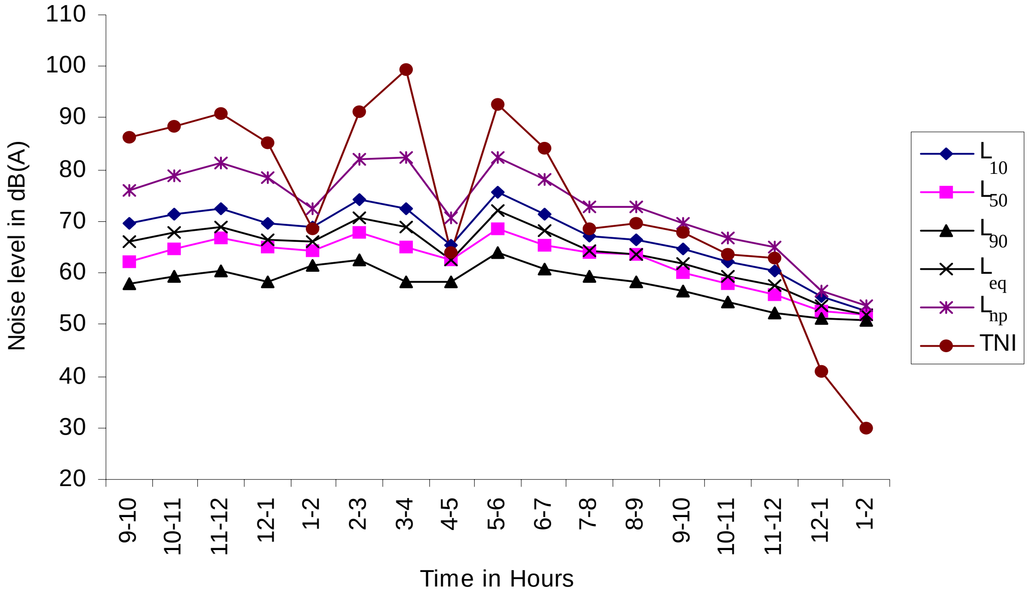

Fig. 4.7 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI for Tilkanagar

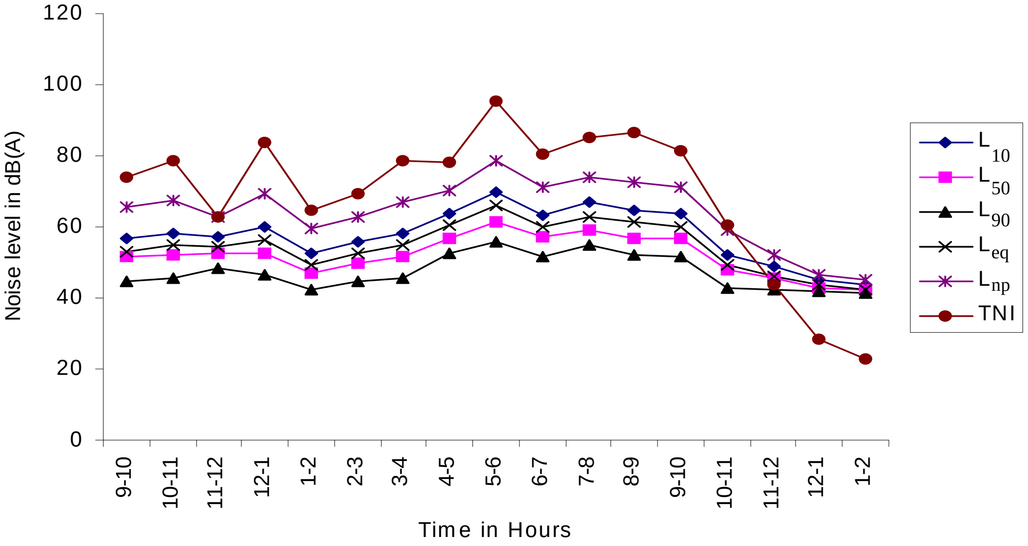

Fig. 4.8 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI for Dumerta

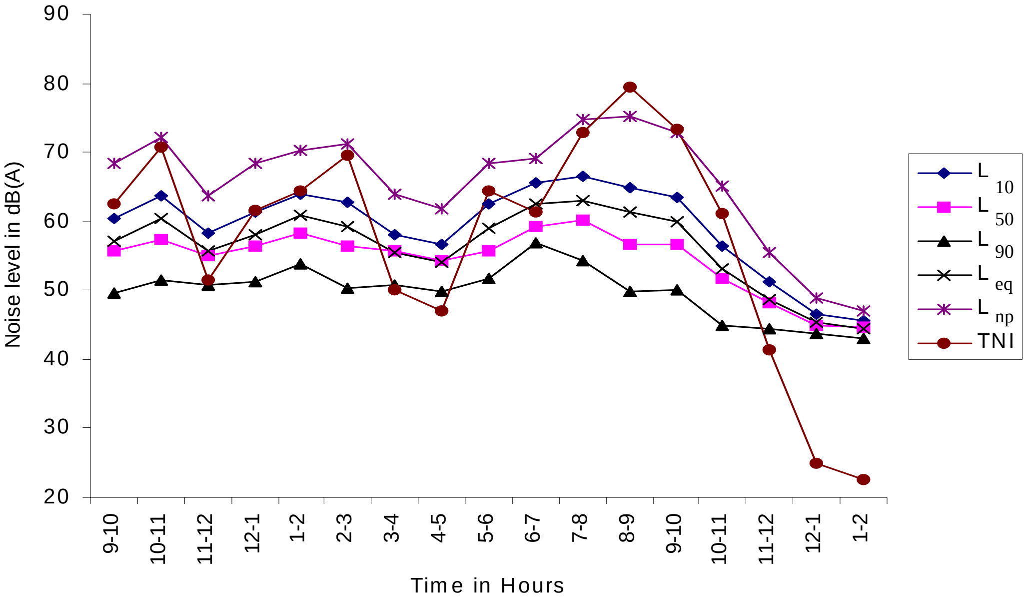

Fig. 4.9 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI for Gundichapalli

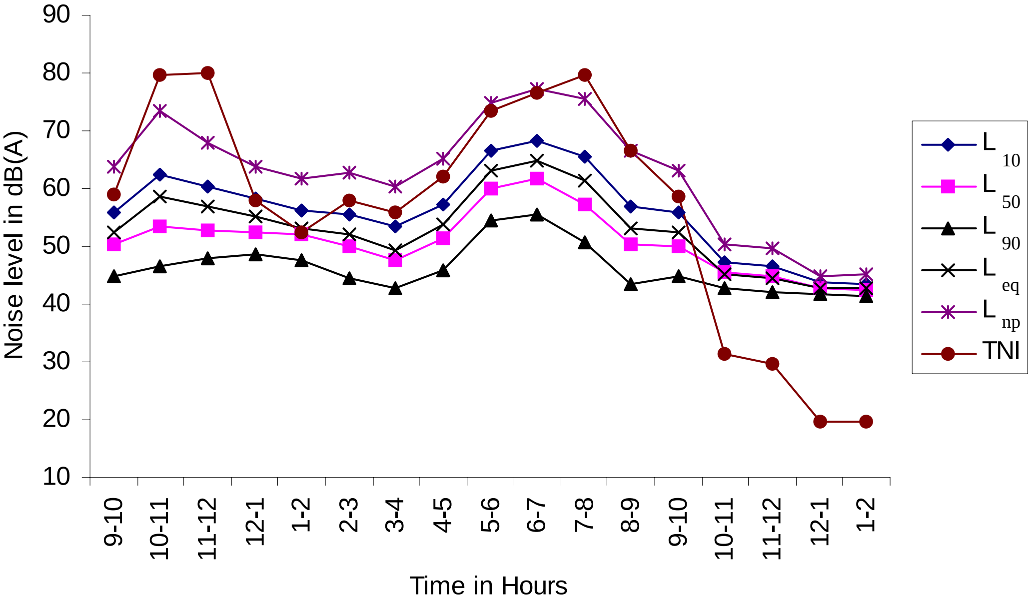

Fig. 4.10 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI for R. S. Colony

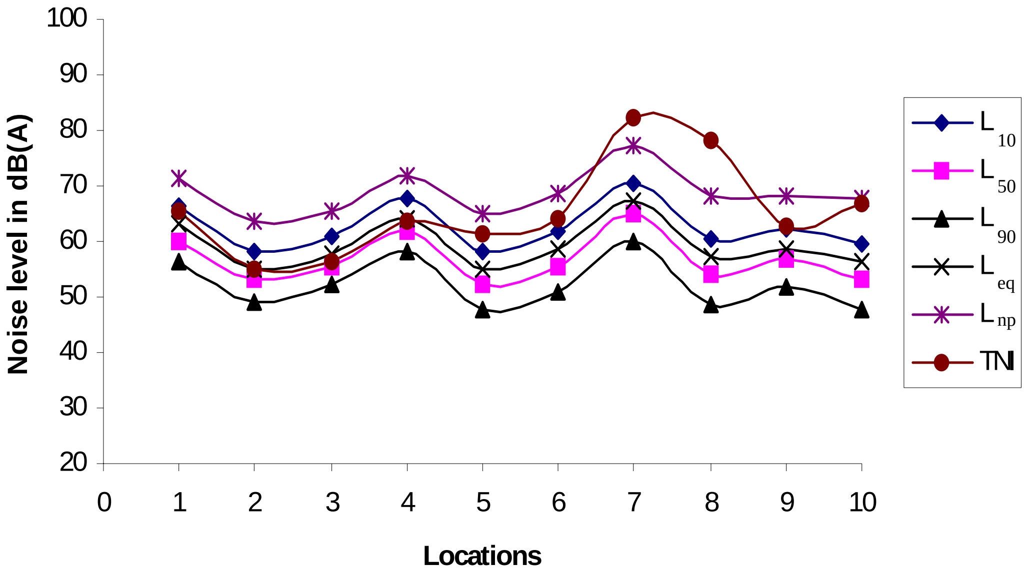

Fig. 4.11 Average Ambient Noise Levels of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI for Various Locations in Bondamunda During Day Time

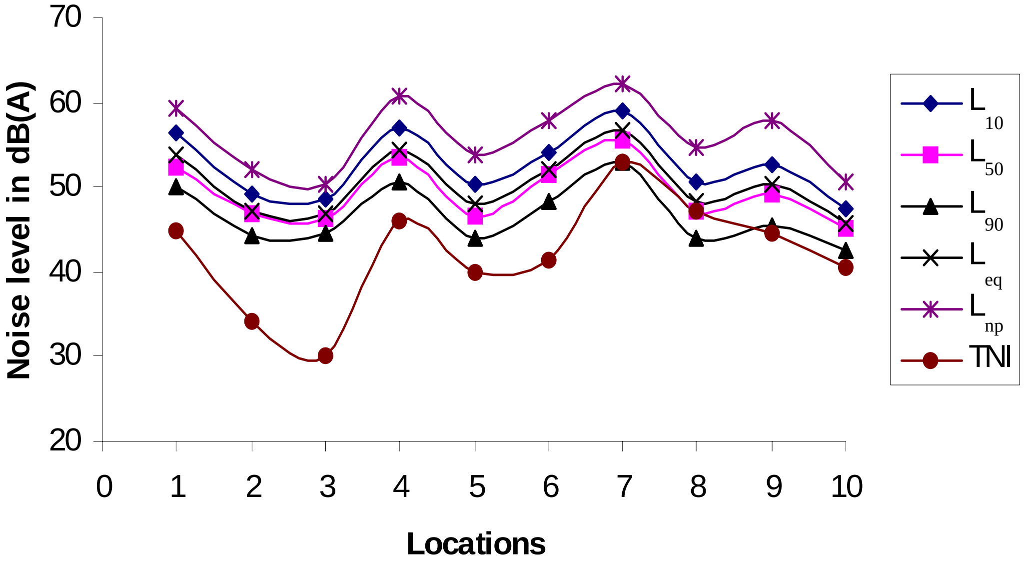

Fig. 4.12 Average Ambient Noise Levels of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np} and TNI for Various Locations in Bondamunda During Night Time

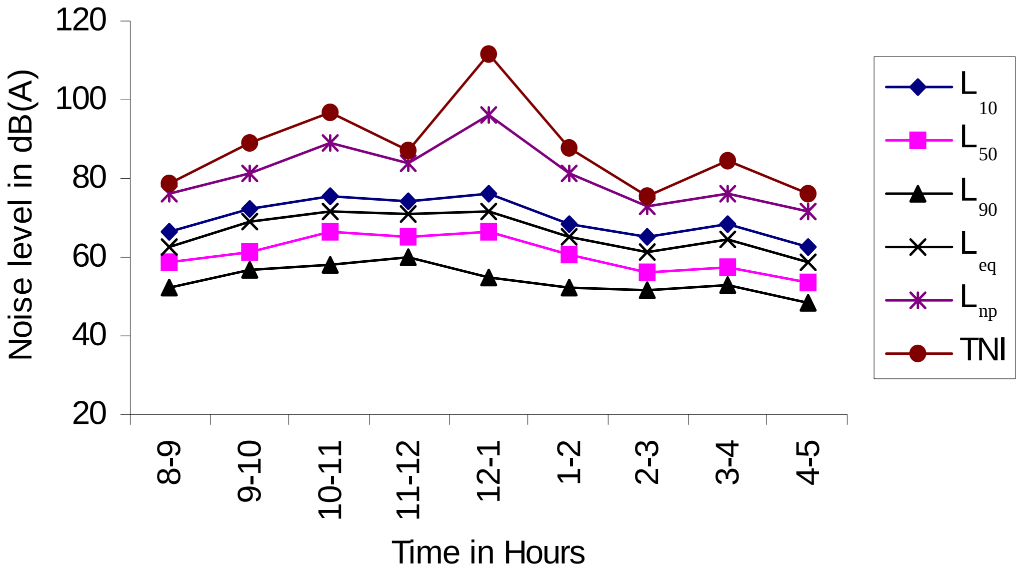

Fig. 4.13 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np}, and TNI for Post Office

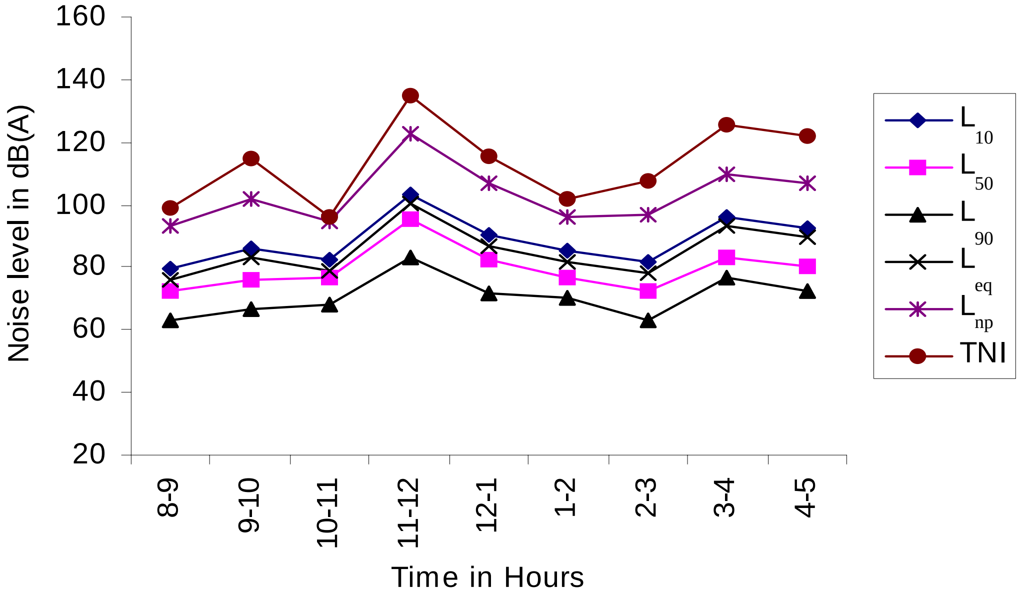

Fig. 4.14 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np}, and TNI for Railway Station

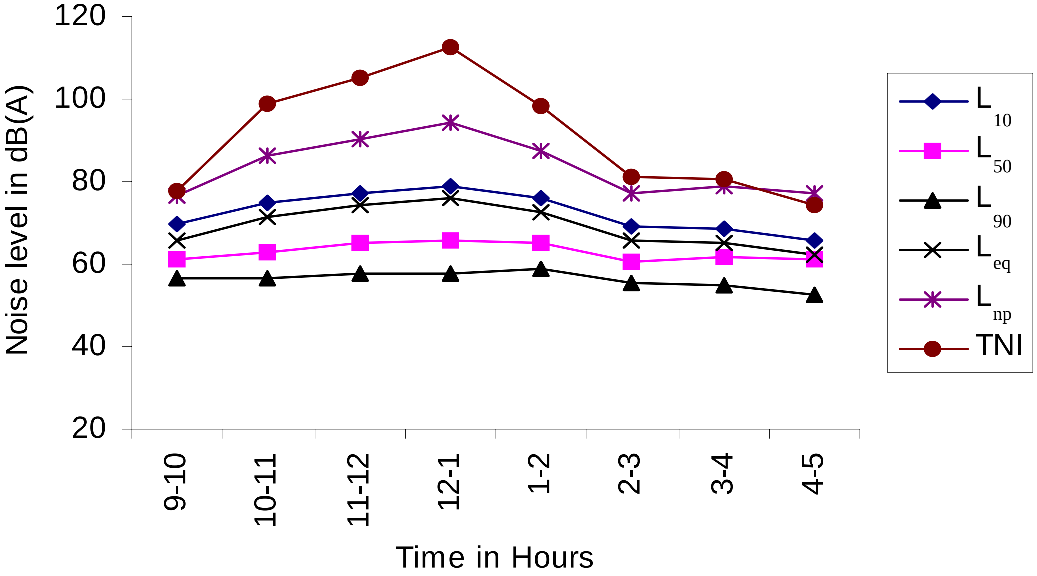

Fig. 4.15 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np}, and TNI for Bank

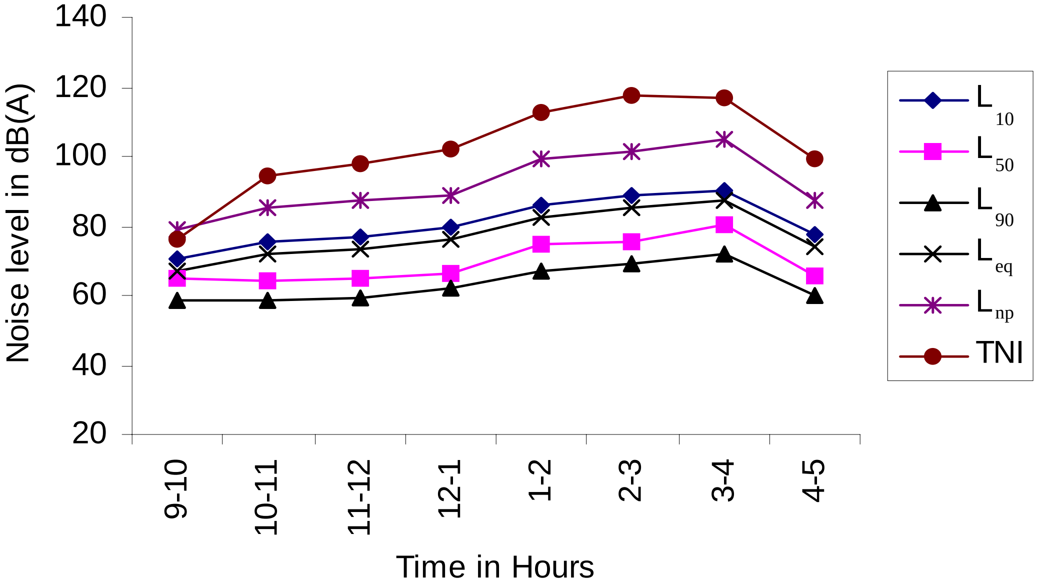

Fig. 4.16 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np}, and TNI for Local Market

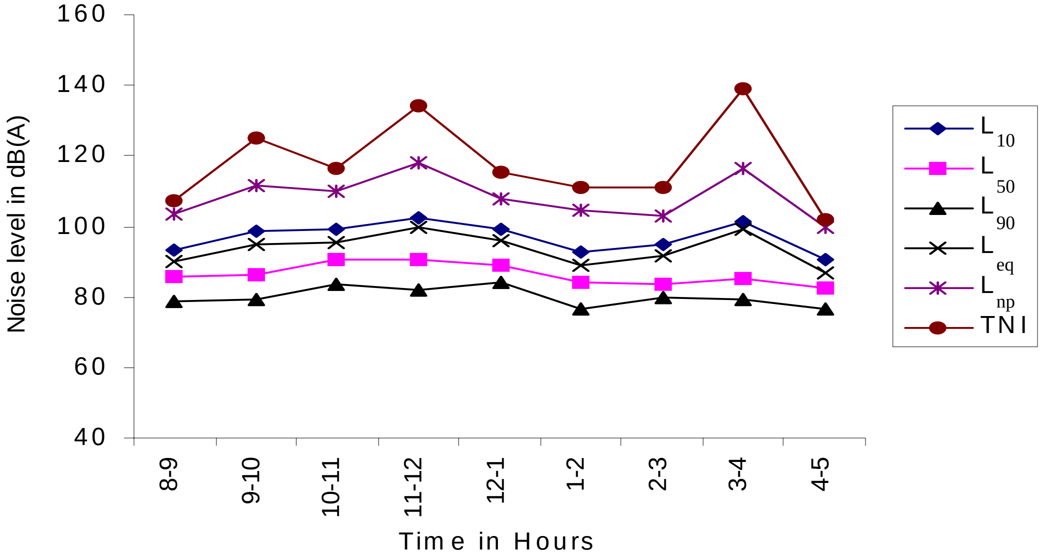

Fig. 4.17 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np}, and TNI for Locoshed

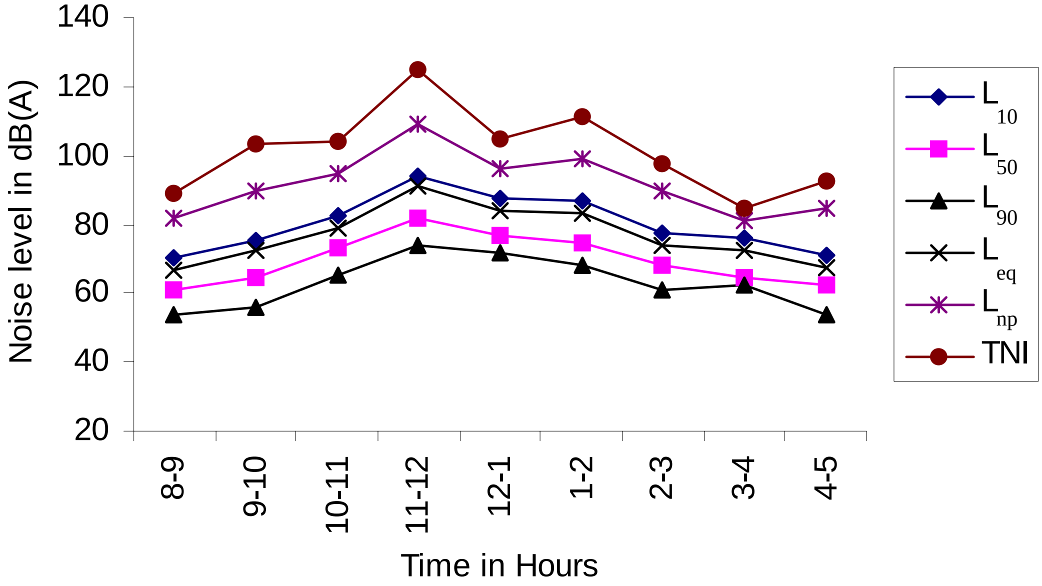

Fig. 4.18 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np}, and TNI for Marshalling Yard

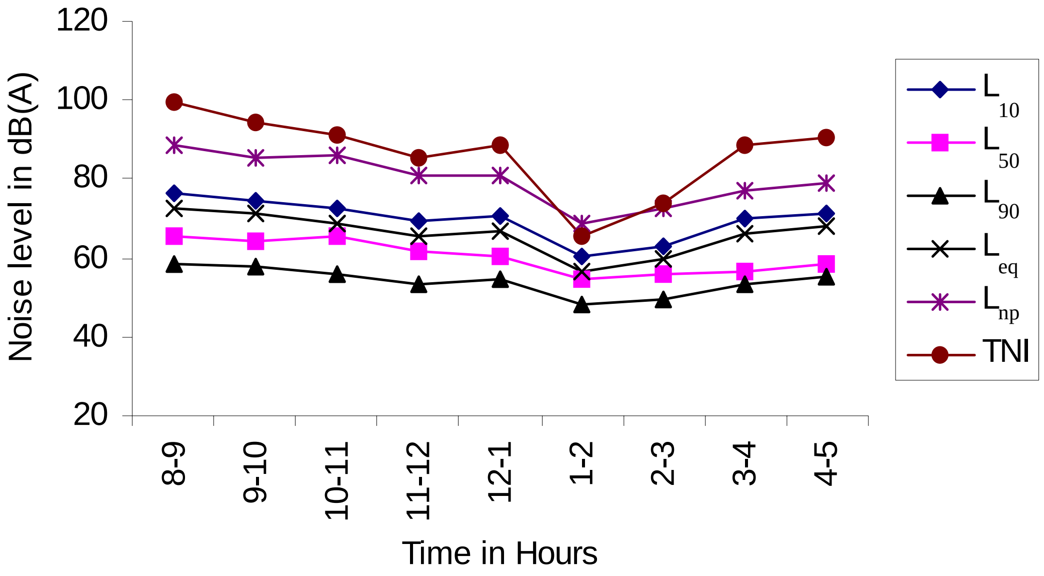

Fig. 4.19 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np}, and TNI for Hospital

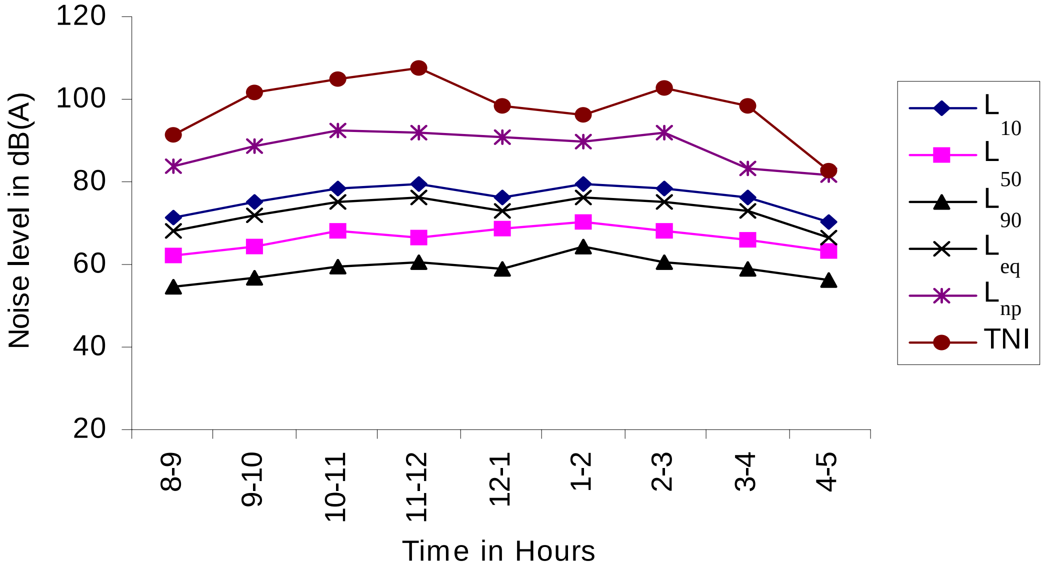

Fig. 4.20 Hourly Variation of L_{10}, L_{50}, L_{90}, L_{eq}, L_{np}, and TNI for College

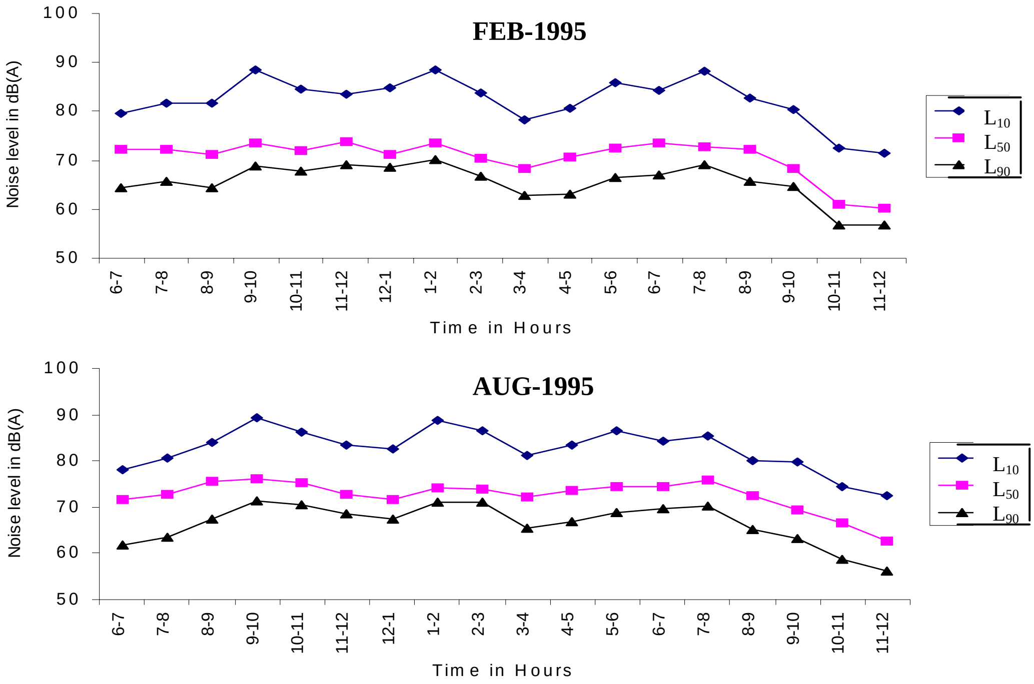

Fig. 4.21 Hourly Variation of L_{10}, L_{50}, and L_{90} of February-1995 and August 1995

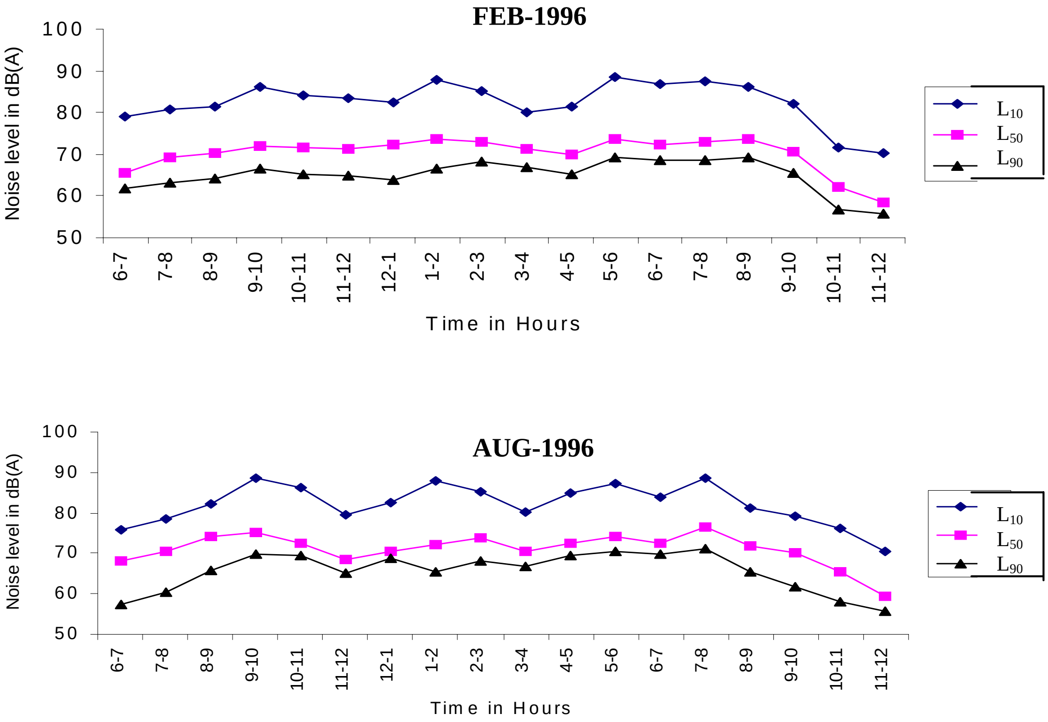

Fig. 4.22 Hourly Variation of L_{10}, L_{50}, and L_{90} of February-1996 and August 1996

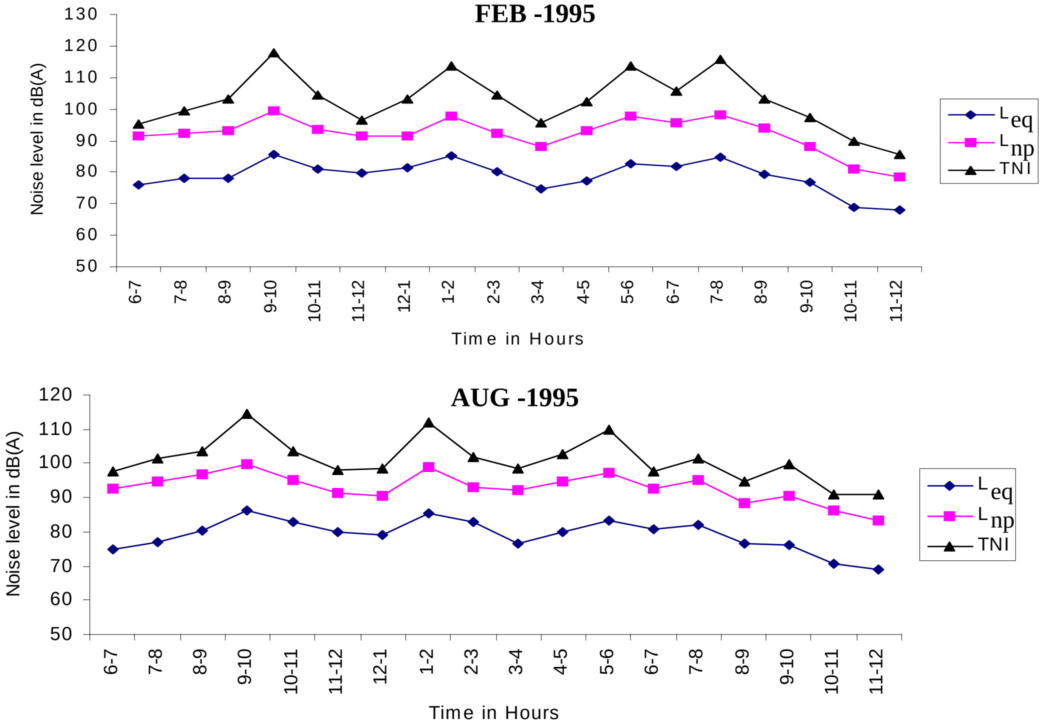

Fig. 4.23 Hourly Variation of L_{eq}, L_{np}, and TNI of February-1995 and August 1995

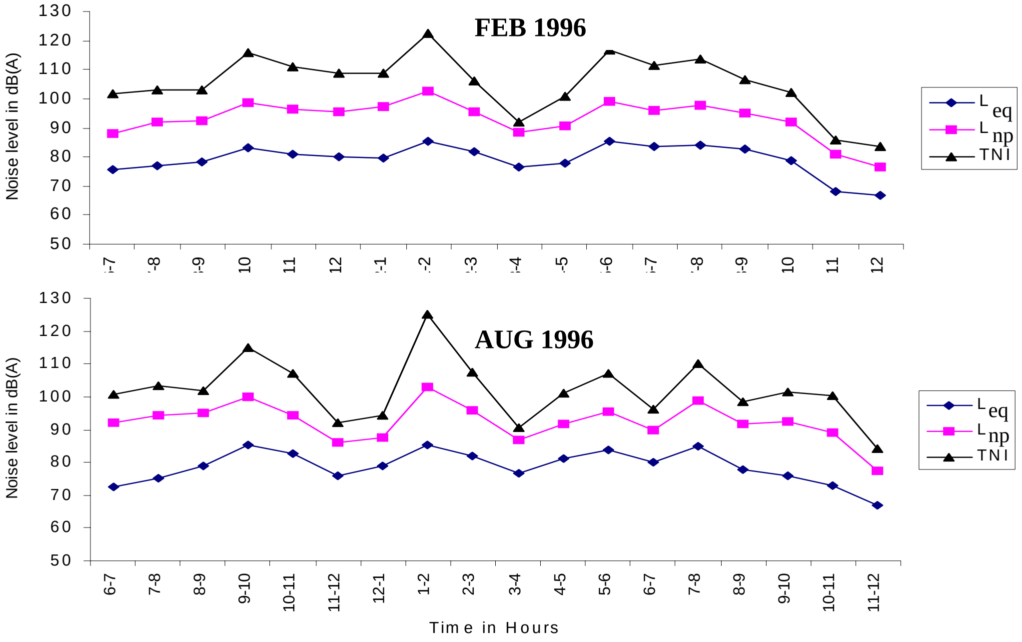

Fig. 4.24 Hourly Variation of L_{eq}, L_{np}, and TNI of February-1996 and August 1996

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter includes the brief discussion of the results found and conclusion and recommendation are given.

5.1 SUMMARY

The study area experiences a seasonal climate and can broadly be divided into three seasons i.e. summer (March to June), rainy (July to October) and winter (November to February). The minimum and maximum average ambient temperature in the study period was 8.0^0 C and 47.0^0 C in January and May, respectively.

The analytical data of various physico-chemical and metallic parameters indicates that some parameters like Electrical Conductivity, Total Hardness, Calcium, Magnesium and Iron are found to be above than the prescribed limit in some samples of the study area. From the statistical analysis high positive correlation was found among the different water quality parameters like Total Solids – Total Dissolved Solids (0.997), Mn – Cd (0.981), Temperature – pH (0.990), Ca – Mn (0.990), Temperature – BOD (0.984) and Total Hardness – Ca (0.991) The WQI value indicates that water samples of some areas, unfit to poor for drinking purposes, may be due to high concentration of iron.

The ambient air quality parameter like SPM exceeds the prescribed limit of residential standard where as SO_2 and NO_x are within the limit. The AQI value indicates that, the air environment is clean to heavily polluted category.

The average noise level (L_{eq}) of all the residential area, traffic point and silence zone exceeds the prescribed standard during the study period. The noise levels of commercial areas like railway station and local market exceed the limit between 8.00 AM to 5.00 PM but the bank and post office, the noise level exceeds during the busy transaction hours between 10.00 AM to 2.00 PM

5.2 CONCLUSIONS AND RECOMMENDATIONS

The present study represents an in-depth investigation of the current status of environmental quality of Bondamunda area of Rourkela Industrial Complex over a period of more than two years. The Industrial Complex and its surroundings have been growing fast due to rapid urbanization and industrialization in the last four decades. This has resulted in environmental degradation with regard to water, air and increased noise level. As such the present environmental status of Bondamunda area is not so alarming. However, if proper environmental management is not followed, then the situation may degrade further. The ground water in some localities are found to be polluted due to various industrial activities as well as domestic activities. Some water quality parameters have already exceeded the limit and some parameters are approaching towards the limit because of leaching, percolating and other such phenomenon for ground water. There are various measures which can be made to control the water pollution; however the following measures are important depending on the topographic and metrological consideration of the area under study.

1. Municipal and sewage water should be treated before it is released to the water bodies.
2. For industrial houses, provision of zero emission or minimum emission should be enforced.
3. Proper planning should be implemented before allowing any body to draw the water from under ground.
4. Ground water used for infant feed must be pretreated and preanalysed so as to ensure less health threats.

5. People awareness campaign should be made by the government and non-government organization.

The air quality parameter like SPM exceeds the limit in all sampling stations during summer season where as SO_2 and NO_x within the prescribed limit. The ambient air quality was found to be clean to heavily polluted category. The heavily polluted category is due to high values of SPM present in air in summer season which comes from the dry ground dust lifted up by the wind, vehicular movement and nearby industrial area. The various measures suggested for the prevention and control of pollution in ambient air in the study area includes the following:

1. Greater control of emission in the industries
2. Upgradation of fuel quality and use of cleaner fuel.
3. Compulsion of Catalytic Converters for all petrol driven vehicles and particle trap for diesel vehicles.
4. Enforcement of emission standards for vehicles on the road and at the manufacturing stage.
5. Plantation of trees along the road sides to absorb the pollutants and reduce the pollution level.
6. Construction of flyovers and diversion of routes which reduce traffic congestion and thereby pollution level.
7. Proper location of bus stops and bus terminals.
8. Redesign of the main junction which presently slows down the flow due to rotary effect.

The ambient noise level (L_{eq}) at some places exceeded the recommended limit. This is mainly due to

1. Blowing of air horns at prohibited areas.
2. Operation of poorly maintained vehicles.

3. Poor road conditions in the town.
4. The encroachment of road sides, which cause slow movement of vehicles with frequent use of horns.
5. Noise comes from many sources like T.V. chattering among people, occasional passing of scooters, motor cycles, cars and school bus, traffic noise from shops and tiny industrial units etc. in residential areas.
6. Workshop for the maintenance of various parts of machineries used in industrial area.

It is suggested that, the following measures may be undertaken to control the menace of noise pollution.

1. Strict enforcement of existing law to prohibit air horns inside the town.
2. Proper maintenance of the vehicles.
3. Laying good roads and their maintenance.
4. Strict enforcement of the existing law to remove the encroachments on road sides.
5. Plantation of trees like Neem and Coconut and other vegetation inside the town on road sides and around the silence zone will reduce the noise levels.
6. Parks should be maintained properly around the houses to reduce the domestic noise pollution.
7. Workers in noisy industrial environments should be provided with some form of ear protection (ear plugs, ear mufflers and other ear protective devices).
8. Highly noise producing machines can be kept in isolated buildings and glass cabin can be provided for the operator.
9. Educating people about the hazards of loud sound and restriction on the use of pressure horns, loud speakers and fire crackers shall play an important role in mitigating sound.

LIST OF PUBILICATIONS

Sl.No. Paper

1. Physico – Chemical Analysis of Some Community Ponds of Rourkela.1996. Indian J. Env. Prot. 16 (9):679-684.

2. Status of Water Quality at Bondamunda of Rourkela Industrial Complex, Part – I, Physico – Chemical Parameters. 1998- Indian J. Env. Prot. 18 (5):346-353.

3. Assessment of Mass Bathing on River Brahamani during Maha – Shivaratri Mela, March – 1997 at Vedvyas . A Case Study – 1998. Indian J. Env. Prot. 18 (7) : 516-519.

4. Status of Ambient Air Quality at Bondamunda of Rourkela Industrial Complex. 1998. Poll. Res. 17 (1):47-49.

5. Traffic Noise Pollution at Bondamunda of Rourkela Industrial Complex. 1999. Poll Res. 18 (4) : 475-478.

6. Status of Noise Pollution Level at Bondamunda of Rourkela Industrial Complex. 2001. Poll. Res. 20 (1) : 41-46.

7. Status on Water Quality of River Brahamani in Sundargarh District, Orissa 2001. Indian J. Environ & Ecoplan. 5 (2):397-402.

8. Status of Water Quality at Bondamunda of Rourkela Industrial Complex, Part – II, Metallic parameters 2001. Indian J. Environ & Ecoplan 5 (1) : 115-118.

9. Status on Noise Pollution Levels in Residential Areas at Bondamunda of Rourkela Industrial Complex, 2003. Poll. Res. 22 (3) : 433-438.