THE EFFECT ON WATER OF TUNIA RIVER DUE TO POLLUTION OF THE INDUSTRIALIZATION AND URBANIZATION

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

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CONSERVATION OF RIVERS AND LAKES

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in this dissertation entitled, **"THE EFFECT ON WATER OF TUNIA RIVER DUE TO POLLUTION OF THE INDUSTRIALIZATION AND URBANIZATION"** in partial fulfillment of the requirements for the award of the degree of **Master of Technology in Conservation of Rivers and Lakes**, submitted in Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee is an authentic record of my own work carried out during the period from July, 2005 to June, 2006 under the supervision of Dr. D.K. Srivastava, Professor, Department of Hydrology, Indian Institute of Technology, Roorkee and Shri M.K. Singhal, Senior Scientific Officer, Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee.

The matter embodied in this dissertation has not been submitted by me for award of any other degree.

Date: June, 19, 2006
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This is certified that the above statement made by the candidate is correct to the best of our knowledge.

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ABSTRACT

The Tunia river is a tributary of the Champamati river in the Bongaigaon district of Assam. The water of the Tunia river has gradually deteriorated due to industrialization and urbanization of Bongaigaon town. Various types of effluents are discharged into the Tunia river from the refinery and petrochemical units, railways, tea estate, carbon industries, hospitals, hotels and restaurants, automobile repair units, and service centres alongwith other tertiary industrial units. The river also receives the sewage water from the Railway colony, New Bongaigaon railway station and Bongaigaon town.

All discharging effluents and sewage to the Tunia river ultimately go to the river Brahmaputra through the Champamati river. The water quality of the Tunia river is deteriorating day by day due to discharging of effluents from the aforesaid industrial units and sewage water from the Railway colony and Bongaigaon municipal area. As a result, fish and other aquatic fauna are likely to disappear in the said river system.

To study the pollution level of Tunia river, nine numbers of sampling stations are selected along the stretch of the Tunia river and one at the Champamati river.

The water of the Tunia river collected at the various sampling stations and effluents from the different point sources has been analyzed for the physico-chemical parameters such as physical, organic, mineral, other inorganic, and bacteriological parameters such as total coliform and faecal coliform. The water

quality has been evaluated on the basis of the percentage saturation of dissolved oxygen, biochemical oxygen demand, CPCB and ISI classification are used for the designated best use for the various purposes. The comparison of the water quality of aforesaid classification reflects the extent of pollution at respective sampling stations and different point sources which help us to take necessary measures against the pollutional load in the river.

The algal analysis and identification, and bio assay test has been done to ascertain the exact pollutional level in the river water. The NSFWQI and Palmer's algal index are used to evaluate the pollutional level in a river water. The NSFWQI are mostly used in the USA and also applicable in the Indian water environment. Descriptor words and colours are used against the numerical index value as proposed by NSFWQI to evaluate the pollutional level in the water bodies. A comparative index analysis for the monsoon, postmonsoon, winter and premonsoon periods indicates the exact status of pollutional level in the Tunia river.

Palmer's algal genus index and Palmer's algal species index are applied to evaluate the pollutional nature and status of the river. Both the index ascertain that the water of the Tunia river is under pollution in respect of the organic pollutional load from the various sources.

The percentage saturation of dissolved oxygen and biochemical oxygen demand classification indicates that the Tunia river is facing under the organic pollutional load and before confluence with the Champamati river the water quality is slightly improved due to self purification process in the river.

The various classification such as CPCB, ISI, NSFWQI and Palmer's algal index reveals that the Tunia river is under the problem of organic pollutional load.

The water of the Tunia river contains high numbers of total coliform and faecal coliform which indicates the presence of pathogens in the river water. Therefore, the Tunia river water always spread the water brone diseases in the downstream area after the flood hazards.

The effluents and sewage water from the various sources affect the flora and fauna in the river water. Abundant of nutrients in the water initiates algal bloom, overgrowth of water hyacinth and willy growth of other aquatic plants along with the eutrophication hazards creates ecological problems. The polluted water also affects the fish and other aquatic fauna in the river water.

Therefore, the adverse effects of urbanization and industrialization first affect the physico chemical parameters in the water and subsequently, affects the whole river eco-system.

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OECD	Organisation for Economic Cooperation and Development
O&G	Oil and Grease
OP	Organic Pollution
ODR	Odour
pH	Negative Log of Hydrogen Ion Concentration
RPI	River Pollution Index
SPC	Specific Conductance
SS	Sampling Station
TC	Total Coliform
TDS	Total Dissolved Solids
TEMP.	Temperature
TKN	Total Kjeldahal Nitrogen
TN	Total Nitrates
TP	Total Phosphates
TS	Total Solids
TSS	Total Suspended Solids
TUR	Turbidity
VLOP	Very Light Organic Pollution
WPCF	Water Pollution Control Federation
WQI	Water Quality Index

NOTATIONS AND ABBREVIATIONS

Symbol / Abbreviation	Meaning / Explanation
ACI	Assam Chemical Industries
Amm. N.	Ammonical Nitrogen
APHA	American Public Health Association
AWWA	American Water Works Assocation
BCL	Brahmaputra Carbon Ltd.
BOD	Biological Oxygen Demand
BRPL	Bongaigaon Refinery and Petrochemicals Ltd.
BRFM	Bongaigaon Roller Flour Mills
CEQ	Council of Environmental Quality
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
C&WW	Carriages and Wagon Repair Workshop
DBU	Designated Best Use
DO	Dissolved Oxygen
DW	Discriptor Words
FC	Faecal Coliform
HOP	High Organic pollution
IV	Index Value
ISI	Indian Standard Institute
MOP	Moderate Pollution
MPN	Most Probable Number
NB	New Bongaigaon
NEGPL	North East Gases Pvt. Ltd.
NFR	North East Frontier Railways
NOSLP	No Or Slight Pollution
NSFWQI	National Sanitation Foundation Water Quality Index
NTU	Nephelometric Turbidity Unit

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CHAPTER – 1

INTRODUCTION

1.1 GENERAL

The rapid industrialization and urbanization and extensive use of fertilizer and agro-chemicals along with other chemicals have put in severe strain on the river eco-system. Gradually, increasing pollution of river water has become a matter of great concern in recent years. Basically, the growing population and subsequent urbanization and industrialization are main unabated polluting causes of the rivers in the world.

Industrialization and urbanization are growing hand in hand to form modern technological society. Subsequently, it affected adversely the neighboring water resources along with the natural environment. The growth of modern technology and industry has initiated to increase the population in urban settlements.

The urban area occupies roughly 0.3 % of world's geographical area and about 40% of the World's population resides in this urban area. The dynamics of industrialization and increase of population has led to the growth of the large modern urban complexes. Consequently, high density of population, high consumption of energy, large amount of solid wastes generation, discharge of domestic sewage and industrial effluents are the distinctive character of both industrialization and urbanization. The river, therefore, has been affected by the above causes in respect of the morphological and ecological aspects.

1.2 STUDY AREA

Bongaigaon is an industrial town in the lower Assam and the Tunia river is flowing through the town. The development is growing after commissioning of Bongaigaon Refinery and Petrochemicals Ltd. (BRPL). Earlier, Birjhora Tea Estate and C&W Workshop, NF Railways was setup at Bongaigaon to open industrial development in that area. Bongaigaon Refinery and Petrochemicals Ltd. was established in 1974 on the bank of the Tunia river. After commissioning of BRPL, major subsidiary industrial units such as Brahmaputra Carbon Ltd, Assam Chemical Industries, North East Gases Pvt Ltd, Indane Bottling plant, Bongaigaon Roller Flour Mills, Oil India Pumping Station, Anjil Plastic Industries, Sapphire Oil Industries Ltd, Viswakarma Plastic Works and other small industrial units were set up under the private and public sectors. This has initiated the massive industrial growth in the area. Some tertiary industries such as laundry, hotel, restaurant, patholab and nursing home etc are growing in and around the Tunia river.

Earlier, the water of Tunia river was being used by people for domestic purposes such as drinking, bathing, cleaning and other aesthetics purposes. Now, the water can not be used for this purpose due to heavy organic pollution and the river carries effluent and domestic sewage from the aforesaid industrial units along with the Railway station and Railway colony, New Bongaigaon and Bongaigaon municipal area.

1.3 LOCATION OF POINT SOURCES

All pollution load are concentrated in between the BRPL outlet to the Bongaigaon town. The river ecosystem of this 5 km long stretch of the Tunia river has been completely deteriorated and consequently, fish and other aquatic fauna are not found in this area of river.

The location of the point sources are Dhaligaon, Kukurmari and New Bongaigaon, BRPL discharges effluent at Dhaligaon. Similarly, Brahmputra Carbon Ltd., North East Gases Pvt. Ltd. and Bongaingaon Roller Flour Mills discharges effluent at Kukurmari. C&W workshop, New Bongaigaon Railway station and Railway colony also discharges effluent at New Bongaigaon area. Other small industrial units including waste water of Bongaigaon town has been discharged into the Tunia river in the town area.

1.4 ORGANIC LOAD

The Tunia river receives about 2439 kg of organic load per day from the industrial units. Out of which 149 kg are easily biodegradable and 2290 kg are less biodegradable. The river also receives about 2653 kg of easily biodegradable organic matter from the domestic sources.

1.5 OBJECTIVES

The water of the Tunia river is gradually deteriorated due to urbanization and industrialization. Therefore, it becomes necessary to assess:

1. Identify and list the sources of pollution of the river.
2. Present status and pollution load of the river.
3. Water quality status as per the CPCB's norms.
4. Assessment of the river water quality with the help of water quality indices.
5. Effect of flora and fauna of the river.
6. Indicate the progress of self-purification capacity of the river.
7. Assess the factors for deterioration of biotic and abiotic parameters.

8. Some remedial measures for preventing the degradation of vulnerable resources.

1.6 EFFECTS OF URBANIZATION

Urbanization has major impacts on water resources and water quality in a neighbouring water system. The urban development may be the primary project being evaluated or urban expansion may represent a secondary impact resulting from the project of primary concern. Industrial expansion, highway construction, airports and other types of development tends to spur additional urban or suburban expansion.

The urban or suburban growth results in increased water demand for the basic needs. Consequently, it leads to additional stress on existing surface and ground water resources, water treatment system and water distribution system. The increasing concentration of population has also invited the concentration of pollution sources. As a result, the rate of environmental degradation has exceeded the rate of natural purification.

The impact of urbanization growth is the increase in waste water flows and loads [77]. This may overload the existing sewers and treatment facilities resulting in significant decrease in water quality of receiving water bodies. A positive aspect of urbanization is the possible elimination of septic tanks and outdated sewage treatment plants in outlaying areas, which are swallowed up the expansion and as a results, it makes to improve water quality in surface water and as well as ground water.

Urbanization also influences run off from the area. The proportion of impervious land area had been increased and resulting in increased quantities of run off and reduced flow time. Consequently, storm water may drastically changes the natural drainage system. Storm water from the urban and suburban areas may add a significant pollution load to the receiving stream. Dust and chemicals deposited on the land surface are conveyed by the storm water run off. Increased urbanization and associated industrialization result in more rapid accumulation of various pollutants on the earth surface. Sartor et al (1974) found that about 1400 lb of total solids, 95 lb of COD, 1.10 lb of phosphate and 2.20 lb of Kjeldahl nitrogen per square mile on the surface of city streets [83]. Also presents in material on urban streets were heavy metals, pesticides and coliform organisms.

Urban and suburban development may also result in increased erosion, particularly during the development stages. Keller (1962) observed that the erosion of lands undergoing transition from rural to urban use in the vicinity of Washington, D.C. caused increase of about 17 ton/mil.^{2}-yr in suspended sediment in local streams [46]. Scheidt (1967) reports increases of 1000 to 121,000 ton/mil^2.yr in erosion from lands undergoing urban development [84]. Dallarie (1976) describes erosion rates of 69 ton/acre-yr for disturbed urban lands and 0.5 ton/acre-yr for well established urban areas [19]. Guy and Ferguson (1962) noted that urban construction produced about-39 tons of sediment per acre [38].

Urban and suburban growth may also result in additional secondary impacts on water quality due to additional industrial, commercial and institutional growth, all of which to increase pollution flow and loads.

Increase of population beyond urban absorption capacities in respect of space, power, water, transport, handling of wastes and treatment of sewage of a city initiate to slum, social stress and urban unemployment; ultimately which affect the whole natural environment.

1.6.1 Harmful Effects of Urbanization

The following harmful effects of urbanization include:

1. Sewage and domestic waste water are excellent medium for the growth of pathogenic bacteria, viruses and protozoa. These introduced into the river water cause deleterious effects and water brone diseases in man and animals. The water brone diseases such as viral hepatitis, polio, cholera, dysentery, typhoid and ameobiasis are easily spread out through the polluted water.
2. The domestic sewage makes the water extremely anesthetic. Water becomes totally unfit for drinking of domestic use.
3. The ova and larvae of many worms are parasitic to man. They may pass out in urine and faeces thereby contaminating the receiving water.
4. Sewage and domestic waste water containing oxidisable and fermentable organic matter causes depletion of dissolved oxygen in the receiving water bodies affecting the aquatic flora and fauna severely.
5. Oxygen deficiency also leads to the production of objectionable odours in water.
6. Presence of solid matter floating in suspension, colloidal and pseudo-colloidal dispension in sewage creates serious water

problems such as blanket the stream thereby interfering with the spawning of fish, reduction of aquatic biota and deterioration of river bed.

7. Accumulation of sewage and domestic waste waters in receiving water bodies retards the self regulatory capabilities of aquatic organisms. Self purifying ability of water is lost and it becomes unfit for domestic purposes.
8. Discharge of nutrient rich sewage and domestic waste water in combination with industrial effluents and wastes poses serious health problems in man.
9. Sewage and waste water have a tendency to grow eutrophication in the water bodies.
10. Sewage and domestic waste water always threat to water courses.

Generally, these effects has been observed in the nearby river which flow near the urban area. The effects may be vary as per depend on location, natural environment and way of living standards in the urban area.

1.7 EFFECT OF INDUSTRIALIZATION

Industrialization leads to increase in the quantity of waste water and waste materials which ultimately affect the nearby water resources. The nature of polluted water is completely different as per the industrial activities. The waste water from mining industries varies greatly depending upon the kind of mining activities. Similarly, the waste water varies largely according to the difference in the manufacturing process even among the same type of manufacturing industries.

The US News and World Report (1977) stated that about 1000 new chemicals are produced by US industry in every year [98]. In this report, it is also mention that more than 12,000 chemicals are toxic, 1500 are suspected of causing tumors and 30 compounds at that time were known to cause cancer.

Industrialization contributes to concentrate the people around the industry ultimately which initiates the first step of urbanization. As a results, the water quality of the neighbouring river will gradually deteriorate due to discharge of waste water and waste materials into the water bodies. The pollution resulting from increased human activities is threatening several rivers characterized by eutrophication and the occurrence of dramatically low dissolved oxygen (Jhingran, 1991; Konar et al., 1997) [44, 48]. Similarly, the Nile river is also receiving sewage and industrial effluents from many towns flanking the river (Kenawy and Hamzan, 1997) [47]. The water quality of the river are, is to be changed resulting from a proposed action or project. Pollution of a river first affect its chemical quality and then systematically destroys the community disrupting the delicate food web. (Awasthi and Shrivastava, 1998) [10]. Phosphorous and nitrogen inputs from domestic wastes and agricultural fertilizers accelerates the process of eutrophiation of aquatic environment (Schindler, 1971; Vass et al., 1989) [85, 99].

Industrial effluents discharged into water bodies contain toxic chemicals, hazardous compounds, aliphatic and aromatic compounds, cyanide, metallic wastes, plasticizers, toxic acids, corrosive alkalies, oils, and grease, dyes, biocides, biodegradable and non biodegradable matter, radioactive wastes and thermal pollutants from numerous industrial units [88].

Due to receiving of such type of compounds, the river eco-system is gradually degraded ultimately which impacts the flora and fauna of the river.

Impact may be classified as primary or secondary. The proposed action initiates the primary impact for their operation. The location of a major industry has a primary impact on water quality of neighbouring water resources due to discharge of industrial waste water. The said proposed industry also initiates to promote additional urban and residential development resulting increase of domestic waste water flows from the additional residential areas as a secondary impacts.

1.7.1 Harmful Effects of Industrialization

The following harmful effects of industrialization include:

1. Industrial waste water impart colour, foul, odour and turbidity to the receiving waters. They undergo putrefaction to form objectionable taste.
2. Heated effluents discharged into water system may severely alter the aquatic ecosystem by increasing the temperature of the stream.
3. Toxic effluents may inhibit the natural purification process of the water bodies.
4. Industrial effluents cause deleterious effects on living organisms and may bring about death or sublethal pathology of kidney, liver, lungs, brain and reproductive system.
5. Effluent like methyl mercaptan and pentachloro phenol lower the photosynthetic rate of aquatic plants.
6. Use of disinfectants may cause mortality of fish, planktons and diatoms.

7. Chlorine and chlorinated compounds discharged to water bodies causes heavy mortality rate of fish.

8. Mercury, lead, arsenic, cadmium and cyanide has cropped seriously in water bodies.

9. Mercury poisoning among aquatic organisms has resulted in crippling and often fatal diseases like Minimata in Japan (1950).

10. Industrial effluents consisting of arsenic, lead and cyanide cause cellular degradation in brain which results in figidity, coma, stupor, and numbness.

11. Effluents containing acids and alkalies make the water corrosive.

12. Mineral constituents can be responsible for excessive hardness of the receiving water bodies.

13. Effluent of tannery increases the pathrogenic bacteria such as Anthrax bacilli in the receiving water bodies.

14. Effluents always affect the flora and fauna along with the river eco-system.

The industrial effluents are more complex in nature in comparison to sewage of urban activities. It may also vary in process and technology for the same products. The quality of effluents are different due to depend on industrial activities. Therefore, industrial effluent affects badly the river eco-system with compare to the urban activities.

1.8 POLLUTION OF TUNIA RIVER

The Tunia river receives both effluent and sewage from the industrial and urban activities. The effects are more serious due to complex nature of effluents and sewage. It is not easy to ascertain the overall effects on the river. Besides, the Tunia river receives refinery and petrochemical effluents from the BRPL. Refinery and petrochemical effluents are more complex nature than the effluents of other industrial units because of discharging oil and grease, phenolic and aromatic compounds to the river which is more toxic to the flora and fauna. Oil and grease and phenolic compounds are generally more sensitive pollutants to fish and other aquatic fauna. Therefore, the fish and higher aquatic fauna are gradually depleted from the river.

In view of the above, the water quality of the Tunia river is gradually deteriorated ultimately which affect the morphological and ecological system of the river.

REVIEW OF LITERATURE

2.1 INTRODUCTION

The environmental issues had dominated after Stockholm conference in 1972 and this has led to growing realization of the problem of water pollution, resulting in a rapid proliferation of hydrobiological studies. As a result, rivers are being studied for the past several years by various departments and researchers of different discipline. Besides this, various conference were held to focus the attention of the Central and State Government and particularly of the public toward the deteriorating condition of our rivers. The growth of literature and data based on water pollution with special reference to urbanization and industrialization has been influenced after the implementation of the Ganga Action Plan, 1985.

2.2 GENERAL

The growing population and subsequently urbanization and industrialization are unabatedly polluting the rivers. The quality of the river water starting from the sources to the sea is a mirror of the human activities. The water is drawn for use such as drinking, washing, agriculture, industries and other purposes and return to the river as an effluents along the flow path. As a result, due to increasing industrialization and urbanization and other anthropogenic activities, fresh water is becoming an increasingly scarce resources. As population and development pressure continue to grow, most of our water bodies have become polluted (Saluja and Jain, 1998) [81].

Murugesan and Sukumaran (1999) noted that rapid population growth, increasing living standard, wide sphere of human activities, growing urbanization and industrialization have resulted in greater demand of good quality water, while on the other hand pollution of water resources is also increasingly steadily in the future days [60].

The riverine resources of India containing 113 river basin out of which 14 are major, 44 medium and remaining 55 are minor rivers [53]. The fourteen major river basin account for 83 % of the total area of the basin and contributes 85 % of the total surface flow and covers 80% of the total length (Nilay Chaudhuri, 1983) [16]. River basins of 720000 km^2 catchments area characterizes the major rivers (Rao,1979; Jhingran, 1991 and Gopakumar et al., 2000) [76, 44 & 33].

The main cause of river pollution is due to discharge of industrial effluent, domestic sewage, agrochemical and other human activities. Due to river pollution, marine organisms have been decreased by 40% in the last two decades [23]. Regarding to the human health, number of diseases affecting heart, kidney and bones are caused due to pollution of the aquatic system. Nearly 20 lakh people are dying annually due to polluted water in India. The polluted water takes the life of one child in every minute in India.

The Central Pollution Control Board (CPCB) has brought out the amount of deterioration of water quality over the years as per analysis of river water from 1986 to 1977. The Board also indicated that mean BOD values have gone up in all the major river during the last two decades. Water quality assessment in respect of BOD values indicates that Kerala is at the bottom and Maharashtra at the top in 1997.

Regarding to coliform bacteria, the most affected states are Assam, Uttar Pradesh, Gujarat and Tamil Nadu. In respect of chemical pollution, Gujarat ranks first and next followed by Maharashtra, Andhra Pradesh, Tamil Nadu , Uttar Pradesh and Punjab. Recent survey has revealed that almost all major river in India have become highly polluted (Mahajan, 1988) [55].

Earlier, the World Health Organization (WHO, 1985) found that more than 1000 organic compounds are present in river water and effluents [103]. The confluence of such effluents has great impact on the physico chemical and biological character of the river system. The nature and health of the aquatic communities indicate an expression of the quality of water. The gradual increasing high values of physico chemical parameters might have eliminated all the indigenous life leading to the formation of biological desert. (Rana and Palria, 1982) [73].

2.3 SOURCES OF POLLUTION

Pollution of river water associated with industrial and sewage discharge is a global problem. It is reported that about 70% of the available water in India (Citizens report, 1982) is polluted [17]. The chief sources of pollution is identified to be industrial pollution constituting 8-16% of the waste water and sewage comprises 84-92% (Chaudhuri, 1982) [16]. The sources of river pollution in India are tabulated in Table 2.1.

Table 2.1. Sources of river pollution in India

Sl. No.	Name of the river	Sources of pollution
1	Ganga	Industrial, urban and agricultural activities.
2	Yamuna, Delhi	Sewage, DDT factory and other industries and power plant
3	Kali, Meerut (UP)	Sugar mills, distilleries, paint, soap, silk, yarn, tin and glycerin industries
4	Bajora, Bareilly (UP)	Synthetic rubber factories
5	Ganga, Kanpur	Jute, chemical, metal, surgical, tanneries, and sewage
6	Gomti, Lucknow (UP)	Paper and pulp mills and sewage
7	Suvaon, U.P	Sugar mills
8	Siwan, Bihar	Paper, sulphur, cement & sugar mills
9	Damodar, Bokaro	Fertilizers, steel mills, coal and paper plant
10	Sone, Bihar	Cement, pulp and paper mills
11	Hooghly, Kolkata	Paper & pulp, power plant, jute textile, chemical, paint, varnishes, metal, steel, oil, rayon, soap and sewage
12	Bhadra, Karnataka	Pulp, paper and steel industries
13	Cooum, Adyar and Buckingham canal, Madras	Automobiles and sewage
14	Cauvery (Tamil Nadu)	Sewage, tanneries, distilleries, paper and rayon mills
15	Godavari	Paper mills
16	Kulu, Mumbai	Chemical, rayon and tanneries
17	Brahmaputra	Oil drilling, refineries, paper mills and sewage
18	Barak	Paper mills
19	Digboi river	Refineries
20	Dilli	Fertilizers
21	Kolong	Paper mills
22	Bharalu	Sewage and small industries
23	Tunia	Refineries and petrochemicals, railways, small industries and sewages.

Source: Central Pollution Control Board.

2.4 EFFECTS ON RIVER WATER

With the rapid industrialization and urbanization during the last 50 years, most of the Indian rivers are subjected to indiscriminate discharge of effluents affecting water quality and aquatic life (Verma and Shukla, 1969) [100]. Increasing pollution of rivers and other water bodies has become a matter of great concern in recent years (Ambasht, 1990; Dikshith et al., 1990) [5, 26]. The industrial effluent, domestic and municipal sewage produce hazardous effects on aquatic life and ecosystem of the receiving water bodies (Ajmal et al., 1985; Neman and Lal, 1985) [4,6].

The effect on river water due to discharges of industrial effluents and domestic waste water are considered on the following parameters:

1. Effect on physico chemical parameters of the river water,
2. Effect on flora and fauna of the river aquatic system,
3. Eutrophication of the river.
4. Effect on bacteriological parameters,
5. Effect on self purification capacity of the river.

2.4.1 Effect on Physico Chemical Parameters

The physico chemical parameters of a river changes with the receiving of the industrial effluent and sewage water. Most of the effluents have high temperature, high BOD and COD, negligible D.O., high amount of dissolved and suspended solids. Adhikary and Saha (1986) have reported that the effluent from the different types of mills and industries causes the distraction of normal ecosystem of any aquatic system [2].

Sewage consists of urine, night soils, kitchen wastes and detergents. The population of micro-organisms increases due to the process of multiplication which takes place in the presence of high organic load of the sewage. As a result, respiratory activity increase resulting in increase of BOD and depletion of dissolved oxygen. Decomposition of organic matter under low DO condition release, odour into the neighbouring system.

Oil is important pollutant released into the Indian rivers with industrial waste. Oil causes much damage to the aquatic environment due to its hydrophobic nature and its impermeability to oxygen. High concentration of oil and phenol are well documented principal pollutant in the refinery waste water (Ford, 1976; Gaur, 1981) [28,29]. Oil films also retard oxygen intake from the atmosphere and so cause decrease in oxygen content in the aquatic environment. Schramm (1972) states that oil film prevents gaseous exchange and indirectly affects the growth of living organisms [86].

Increased turbidity may cause reduction in light penetration, thereby reducing plant growth and food supply. Turbidity increases through erosion and land drainages. Other sources are mine slurries, sewage, industrial effluents, diaries and waste water from the railway yards etc (Mahajan, 1988) [88].

2.4.2 Effect on Flora and Fauna

The industrial effluent and domestic sewage have affected the flora and fauna of the receiving water bodies. Haslam (1978) described various effects of sewage and industrial effluent on aquatic organisms [39]. She concluded that main effects are;

1. A decrease and loss of the species most sensitive to such pollution,

2. A decrease in species diversity at the introduction site and,
3. Increase in any species actually favoured by this pollution.

Basically pollution is essentially a biological phenomenon in that its primary effect is on living things (Hynes, 1963) [43].

2.4.2.1 Effect on fauna

The fauna of a river is directly affected due to river pollution. The rivers are more sensitive against pollution with respect to the fauna.

2.4.2.1.1 Effect on fish

The industrial effluent and sewage have directly affected the fish life in the receiving water bodies [45]. Thompson and Hunt (1930) noted that small quantity of domestic waste water enhanced the productivity of streams and resulted in greater size, abundance and variety of fishes [96]. Larger amount of wastes decreased the abundance of fish and vary large amounts virtually eliminated some fishes. Similarly, water pollution by effluents discharged from industries has resulted in a marked increase in the incidence of mass mortality and adversely affect on fish life (Pandey et al., 2000) [67] David (1956) noted a great loss of fisheries due to industrial effluents in Bhadra river (Mysore) [22]. At high level of pollution, total elimination of sensitive community takes place (Thomson, 1928) [95].

Fishes are gradually threatening due to increasing pollution in the river. Das (1998) has remarked that industrial effluent, sewage and pesticides has been causing environmental pollution threatening fish life in many water bodies [21]. Pandey (2000) noted that fishes are non-target organisms but usually affected due to increasing in pollution and the accumulated toxicants may reach consumers as they form a staple food for them [66].

2.4.2.1.2 Effect on macro invertebrates

The aquatic macro invertebrates inhabit the bottom substrates of the riverbed in a river. Examples of macro invertebrates includes aquatic worms, snails, clams, crayfish, leeches and many insects.

These are used to detect and evaluate affected river reaches as they are capable of reflecting different human induced deterioration. Thienieman (1954)reported that as conditions become more extreme, diversity decreases, so the number of individuals of the remaining species increases [92].

2.4.2.1.3 Effect on micro invertebrate

The Industrial effluent and sewage directly affect the micro invertebrate in a river [40]. Micro invertebrates are so small and difficult to sample, identify and analyse. These are rotifers, cladocera, protozoa, and copepods. The river bed micro invertebrates reflect the pollutional status of the river. The micro-invertebrates are an integral part of the river (Winner, 1975) [104]. Rotifers play an important role in the ecology of the aquatic ecosystem by serving as an essential food source for invertebrate as well as vertebrate organisms (Herzing,1987) [41]. Rotifers exhibit high population turnover rate in nature (Davis, 1962) and also show a quick response to the environmental change [23].

2.4.2.2 Effect on flora

The flora has been affected by the industrial effluent and sewage discharging into the river. Sensitive species are eliminated and tolerable species grow more. Phosphorous and nitrogen are limiting factor for the growth of aquatic plants in the river which releases form the domestic sewage and agricultural activities.

2.4.2.2.1 Effect on water hyacinth

Water hyacinth is one of the aquatic weeds posing serious problems due to its widespread outgrowth [52]. The growth of the plants is so fast and starts vegetative multiplication by means of stolons. The favourable growth is influenced by the domestic sewage due to high content of phosphorous, nitrogen and other organic compounds. It produces optimum breeding condition of mosquitoes and snails which favours malaria, filaria and bilharzinsis. Industrial effluents always affects on adversely for their growth.

2.4.2.2.2 Effect on algae

Algae are frequently found in polluted and unpolluted water due to the nutritional requirements of algae markedly form one group to another group. Patrick (1949) reported reduction of species diversity due to pollution stress [68].

Green algae live in low pH due to inability of other algae to live at lower level of nutrient supply. Blue green algae live in high pH due to increase ability of organic and inorganic nutrients (Lund, 1945; Mitra, 1961) [54, 58]. Phytoplankton succession is influenced by light fluctuation, temperature and nutrient available. Growth of macrophyte, low pH, DO, High CO_2, NH_3 are responsible for low algal production. Verma and Mohanty (1995) has observed the positive correlation of different groups of algae with different physicochemical condition [101].

Pearsall (1932) and Philipose (1960) are of the opinion that myxophyceae increases in an algal population when nitrates and phosphates are low [69, 71], while Munnawar (1970) states that increase in these two factors favour an abundance of forms other than maxophyceae [59]. Zafar

(1967) also observed an inverse relation of nitrate with maxophyceae and found that blue green algae were high when the nitrates were also high and the phosphate were low [105].

Algae shows the species diversity with the refinery effluent. Gaur (1981) observed that the changes in algal communities along a gradient of decreasing pollution load [29].

Adhikary, (1997) studied the impact of BRPL effluent on algal flora of Tunia river and stated that high pollution load near the BRPL discharge point did not permit large number of algal species to thrive and only a few species were encountered which obviously had profound tolerance to oil pollution [3]. He also revealed that blue green algae are more tolerant to the BRPL effluent than the green algae.

2.4.3 Effect of Eutrophication

Eutrophication has been initiated by the domestic sewage and effluent into river or other water bodies. Seven and Walter (1989) have defined eutrophication is qualitatively as the state of a water body which is manifested by an intense proliferation of algae and other higher aquatic plants and their accumulation in the water body in excessive quantities resulted as bloom due to nutrient enrichment of water [87]. Phosphorus and nitrogen inputs from domestic wastes water and agricultural fertilizers accelerates the process of eutrophication of aquatic environment (Schindler, 1971) [85].

Eutrophication is a burning problem for the aquatic environment. The pollution resulting from increased human activities is threatening the several rivers characterized by eutrophication and the occurrence of dramatically low dissolved oxygen (Jhingran, 1991) [44].

2.4.4 Effect on Bacteriological Parameters

Sewage loaded with human excreta and direct human defecation are the two major sources of the faecal pollution in Indian rivers. Microbiological studies on water quality of major Indian rivers have shown the presence of faecal coliform and faecel *streptococci* as an indication of faecal contamination (Shukla et al., 1992; Gaur et al., 1997) [89, 30].

The high faecal load indicates the high degree of human defaecation by thick urban population on the bank of the river and directly discharge the nutshell into the sewage system ultimately which comes to the river.

The most common and widespread danger associated with the drinking water is directly or indirectly contaminated by sewage, human and animal faecal matter and other wastes (Clark, et al., 1982) [18].

Some coliform are faecal in nature and those reach the terrestrial and aquatic ecosystem via alimentary canal of herbivorous animals. Non faecal bacteria are the normal inhabitants of soil (Salle, 1971) [82]. Thelin and Gefford (1983) observed that the number of faecal coliform bacteria released from 30 days old faecal deposits amount to several millions per 100 ml [93]. The survival and multiplication of total coliform bacteria species in water depends upon several factors like temperature, light, various chemicals, which are directly proportionate to the amount of sewage and human interferences (Hiraishi et al., 1984) [42].

The content of E. coli in open water bodies varies with seasons and their level sharply increase after heavy rainfall (Voznaya, 1981) [102]. The *Escheria coli* and coliform group or organisms as a whole has been recommended for the detection of water quality. Concentration of coliform bacteria is usually as an index of civic pollution.

2.4.5 Effect on Self Purification

Accumulation of sewage in water bodies retards the self regulatory capabilities of aquatic organisms. Self purifying ability is lost and it becomes unfit for domestic purposes [35].

Sewage containing oxidisable and fermentable matter causes depletion of dissolved oxygen in the receiving water bodies. Presence of solid matter flowing in suspension, colloidal and pseudo-colloidal dispersion in sewage creates severe water problems. When industrial effluents is discharged through sewage system, this adversely affect the biological purification mechanism of sewage treatment and put an adverse effect on the receiving water body.

2.5 CHEMICAL INDICATORS OF POLLUTION

The concentration of dissolved oxygen (DO) can be used as an good indicator of the polluted river water due to its chemical and biological nature. The rate of deoxygenation reflects the BOD exertion rate in the river water. The reaeration rate is directly proportional to the DO deficit from the saturation value. Regarding this, the state of pollution of a river can be assessed by observing the concentration of dissolved oxygen present in the river water. Similarly, the pollution status of a river can also be judged by using the concentration of BOD present in the river water.

2.6 BIO INDICATORS OF POLLUTION

The bioindicator are species which disappear on exposure to a given pollutant or form abundant population in polluted environment. Therefore, their absence or presence provide some guide to environmental conditions in the river. They includes many macro invertebrates, algae, bacteria and fungi.

The macro invertebrates are may flies, caddis fly, earth worm and paramecium. Algae includes ocillatoria, chlamydomonas, nitzshia, navicula, cladophora, ulothrix and spirogyra. Bacteria are faecal coliform and total coliform. Sewage fungus incudes zoogloea and flavobacterium. Fungi are geotrichum and Leptomitus.

These indicator species may be resistant forms, tolerant forms and sensitive forms. The resistance forms are common sucker, sludge worm and blood worms. The tolerant forms are snails, pond weed and isopods. Similarly, sensitive forms are larvae of caddis fly, dragon fly, stone fly, water mosses and some fishes like small mouth bass (Micropeterus species).

The faecal coliform are most important in river water quality management program. Basically, they are non pathogenic but indicate the presence of pathogan in water which initiate water brone diseases.

2.7 WATER QUALITY INDICES

An index is a means devised to reduce a large quantity of data down to a simplest form. The environmental indicator or sub-index function is calculated which refer to a single quantity devised from one or two polluted variables or characteristic parameters (Ott, 1978) [64]. Basically, it is used to reflect some environmental attribute. Water Quality Index (WQI) is then calculated which is a mathematical aggregation of two or more indicators in some function. Water quality index is simply a numerical value having no units and compare water quality or status to a prescribed base or to a scientific arbitrary standards.

Water quality indices can be formulated in two ways, one is water pollution indices in which index number increases with the degree of pollution and another water quality indices in which index number decreases with the degree of pollution.

Indices that use a numerical scale to represent the gradation in water quality levels were first introduced by Horton (1965) [1]. Brown et al. (1970) has developed a water quality index similar in structure to the Horton's index but with much greater rigour in selecting parameters, developing a common scale and assigning weights for which elaborate delphic exercises were performed [13]. This effort was supported by the National Sanitation Foundation (NSF). As a result, the brown index is also referred as NSFWQI. This is most favourable in assessing the water quality in a polluted water bodies.

A part from this, other indices such as Prati's implicit index of pollution, Mc Duffic's river pollution index, Diniu's water quality index, Dininu's second index, O' Connor's indices, Deininger and Landwehr's PWS index, Walski and Parker's index, Stoner's index, Nemerow and Sumitomo's pollution index, Smith's index, Viet index are used in various countries for assessing the water quality in a polluted water bodies [51].

In this study, NSFWQI is used for assessment and evaluation of pollution status at the sampling station of the Tunia river.

2.8 WATER QUALITY BIO INDICES

The algae is a good bio indicator of pollution. Therefore, algae has been used by many researchers as bio indicators of pollution (Kumar et al., 1974; Nandan and Patel, 1986) [50, 61]. Due to their sensitive nature of pollution, CM Palmer has developed two indices based on algal data for rating the organic pollution of water resources. These indices are algal genus index and algal species index. On the basis of the total score obtained from the assigned number to each genus and species, Palmer formulated pollution index scale for assessing and evaluating the organic pollution of the water resources [65]

2.9 BIOASSAY MONITORING

Indicator species play an important role in the bioassay monitoring to assess the pollution and toxicity level in a river water. Basically, fish and algae are most important species in respect of this aspect.

Algal bioassays are investigated to a great extent regarding refinery and petrochemicals effluents including other industrial waste water. Algae can be usually applied for assessment, evaluation and abatement of organically polluted rivers (Rana and Palria, 1991) [75]. Reddy et al. (1983) have studied the toxicity of oil refinery effluent on physiological responses of algae [79].

Fish are popular and useful test organisms in surveillance and toxicological studies with the logic that if fish life is protected then rest of the aquatic food chain is protected as well [74]. Gray (1980) uses fish for bioassay test to ascertain the water quality status in a river [36].

2.10 TREND OF POLLUTION

The water of the Tunia river in Bongaigaon has gradually deteriorated due to industrialization and urbanization of the Bongaigaon town. The study revealed that the streams of Shillong are grossly polluted with organic wastes (Nath and Gupta, 1993) [62]. Similarly, Gupta (1984) expressed that hilly town Tura is also polluted in a similar way [37]. The water of Barak river and other resources have also deteriorated due to increasing urban and industrial activities in Silchar town (Dutta, 1983) [27]. The river Bharalu in Guwahati city is also polluted due to the similar reason.

The river Jamuna at Delhi, Hooghly at kolkata, Ganga at Kanpur, Allahabad and Varnasi have polluted due to receiving of municipal sewage and industrial effluent. Therefore, all water resources of neighbouring urban area have gradually polluted due to growing human activities.

2.11 SUMMARY

The growing population and subsequent urbanization and industrialization are unabatedly polluting of all rivers in the world. Increasing pollution of rivers has become a matter of great concern regarding study of the river eco system. Most of the studies have been carried out on the basis of physico chemical characteristics of the river and effects of the river pollution on the morphology and physiology of the flora and fauna.

Chemical and bio indicators indicate the pollution status of a river system. Besides, water quality indices, bio indices are used for assessing and evaluating the organic pollution load in a river. Fish surveillance rates can be find out by using bio assay test which can indicate the toxicity level of pollutional load in the river water.

All the studies indicate that it is essential for the proper management of rivers to preserve the river eco-system on the most priority basis in favour of the whole natural environment.

NATURAL ENVIRONMENT OF THE STUDY AREA

3.1 INTRODUCTION

The natural environment is most important for the stable life system in an area. The mutual inter dependence of all lifes, microbial, plant and animals has been influenced by the environmental parameters along with the physical environment of land, air, water and solar energy.

The various environmental parameters influences the environment setting of the Tunia river eco-system. The general information of the Tunia river environment is outlined here under.

3.2 LOCATION

The Bongaigaon town is near about 170 km away on west-north side from the Guwahati city. The town is located having latitude of 26° 28' N and longitude of 90° 33' E. The Bongaigaon district covers the range of longitude 89°-90°96' E and latitude 26° 15'-26°54' N. Basically, the district is located in the north eastern Himalayan sub-region of India.

The Tunia river is located in longitude 90°30'-40' E and latitude 26°18'-35' N.

3.3 BOUNDARY

The boundary of the Bongaigaon district is in North Chirang, East Barpeta, South Brahmaputra river, Goalpara district and West Kokrajhar and Dhuburi district.

3.4 TOPOGRAPHY

The area of Tunia river is generally plain small hills such as Mahadev, Sonakhuli, Mahamaya, Dhagkati, Narikali, Chittonsilas, Bamanipani, Dhumeswari, Boukumari, Nandagiri, Rajachula, Agia, Rokha, Matia, Rendu, Andhermua, Chakrasila, Soonamukh, Tokorabandha, Chandardinga, Tukureswari, Pancharatna and Jogighopa hills are situated on east-south and west-south side of the Bongaigaon town. These hill slightly sloping from north to south.

3.5 GEOLOGY

This area is basically quaternary of sediment comprises of recent alluvial deposits of the Brahmaputra valley. This valley had been evolved during the last two million years by alluviation of the foreland depression or foredeep in between the comparatively young mountain region of the Himalaya on the north and block mountain of the Shilling plateau in the south. Originally, the valley is linked with the phase of uplift glaciation and erosion of the Himalayas along with the tectonics affect of the Shillong massif.

The Jurassic and archean metamorphic rocks with intrusive granite and pegmatite occur in various parts of the area as isolated hillocks and surrounded by alluvium soils [7].

3.6 SOIL

The soil is alluvium and acidic in nature. The colour of the soil is light grey to light brown. Soils are less compact, slightly loose and consist of ground sands, clays and silts.

3.7 FOREST

Major area are covered by reserved forests. The reserved forest are Manas, Bengtol, Bhumeswari, Bhairab, Nakati, Bamungaon, Kakaijan, Chirang and Ripn reserved forest. The Manas reserved forest is famous for its wild life sanctuary in India.

3.8 VEGETATION

The area are generally consists of tropical deciduous and tropical evergreen forest.

3.8.1 Tropical Deciduous Forest

The vegetation consists of *shorea robusta*, *Kydia calycina*, *Alstonia*, *Bombax ceiba*, *Vitex penduncularis* and *Albizzia procera* in the tropical deciduous forest. The *Shorea robusta* occupies above 80% in the vegetation. Similarly, *Ageratum conyzoides*, and *Coffea benghalensis* are most important herbs and *Eupatorium odoratum* are shrubs in the tropical evergreen forest.

3.8.2 Tropical Evergreen Forest

Schima wallichii, *Ficus cumea*, *Michelia oblonga*, *Phoebe goalpaeensis* and *Cinnanomum cecicodaphne* are the important trees in the tropical evergreen forest. In above, *Croton caudatus*, *Phlogacanthus thyrsiflorus* and *Leea crispa* are the common shrubs and herbs in the forest.

3.9 GRASS LAND

There are extensive grassland available on the bank of the river Brahmaputra. The common grasses are *Themeda Villosa*, and *Imperata cylindrica.*

3.10 CLIMATE

The area experiences a subtropical humid climate. The climate of the Bongaigaon district is similar to the entire Brahmaputra valley. The people enjoy 4 seasons such as premonsoon, monsoon, retreating monsoon and winter. The year is climatologically classified as:

Premonsoon	:	March to May
Monsoon	:	June to August
Retreating or Post monsoon	:	September to November
Winter	:	December to February

The summer is fairly hot and highly humid, the winter is moderately cold, foggy and dry. Premonsoon and retreating monsoon have moderate temperature and humidity.

3.11 TEMPERATURE

Air temperature is the most significant factor for affecting and shaping the physical environment in an area. The average temperature in summer is 35-39°C and in winter 9-15°C. The temperature in premonsoon and post-monsoon is moderate in the Tunia river area.

3.12 RELATIVE HUMIDITY

The relative humidity in air is high. It varies from 49 to 100%. Relative humidity is high in summer and low in winter.

3.13 RAIN FALL

The rainfall is similar to that of the entire Brahmaputra valley with some variation due to its location. Basically, this area falls in high rainfall area in Assam. Heavy rainfall occurs in May, June, July and August. Nearly 70% of rainfall occurs during these months. The monthly and annual rainfall of the Tunia river area is shown in the following Table 3.1.

Table 3.1: Rainfall data of the Tunia river area (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1990	21.0	45.7	100.4	461.9	493.2	1082.6	620.6	672.6	676.3	274.0	0.00	0.00	4447.7
1991	20.8	11.4	150.0	266.2	782.9	806.0	605.6	476.3	503.7	96.0	1.20	37.2	3757.3
1992	5.20	58.8	19.2	91.6	375.6	452.4	1032.1	397.7	232.0	110.2	27.2	0.00	2802.0
1993	45.8	139	23.9	104.4	642.8	691.8	1405.4	492.6	219.3	256.4	0.00	0.00	4021.0
1994	36.8	47.0	54.2	318.6	543.8	859.4	204.8	575.2	177.6	128.0	0.6	0.00	3003.0
1995	2.20	21.8	68.0	249.0	495.8	934.0	1022.6	808.4	842.0	124.4	63.2	1.60	4632.0
1996	17.8	0.00	39.8	140.4	795.6	454.4	1438.4	558.8	310.2	201.6	11.2	0.00	3968.2
1997	7.0	25.8	48.2	144.4	216.7	1035.8	320.0	356.2	536.9	25.4	4.80	27.8	2749.0
1998	0.0	9.20	115.2	125.2	342.0	1245.2	936.2	1146	535.8	281.6	0.00	0.00	4736.0
1999	0.0	0.0	8.40	425.6	457	960.0	775.8	695.2	186.8	243.8	7.20	0.80	3761.0
2000	5.3	7.6	12.5	168.1	493.7	137.8	43.8	592.6	284.8	29.8	26.0	5.0	1807.0
2001	1.70	1.8	46.8	259.2	394.2	558.4	555.0	319.8	246.0	319.8	33.2	0.0	2735.9
2002	8.70	4.5	111.2	211.0	173.7	525.2	614.6	132.0	0.0	0.0	7.6	9.5	1798.0
2003	**1.50**	**63.7**	**166.6**	**271.9**	**377.9**	**904.9**	**689.10**	**178.8**	**167.2**	**240.9**	**63.4**	**0.0**	**3125.9**

Source: BRPL and Statistical hand book Assam, 2001, 2002, 2003 and 2004.

The rainy season generally starts from the middle of May and extends up to the end of September. The south west monsoon contributes to about 91 % of the rainfall and north east monsoon as well as premonsoon showers contributes to the rest.

3.14 HYDROLOGY

Bongaigaon district is rich in water resources. The mighty river Brahmaputra flows in the south side of the district. Besides, Manas, Doloni, Aie, Kujia, Tunia, Kanibhura, Durarangi, Saralbhanga and Champamati river are flowing through the entire district from Bhutan to the river Brahmaputra.

3.15 WET LAND

Bongaigaon is rich in wetland and beel ecosystem. Various beels are Dalani, Pitbari, Dalbar, Hatimura, Tamranga, Parpota, Kanara, Kaya, Naldoba, Chatura, Khutamari, Chinabari, Bhakuamari, Bhasamari, Kachharani, Bishpani, Dher Dher, Dim, Khiragur, Dhir & Diple. Tamranga, Dhir, Dalni and Diple are important beels in the district. These wetland imparts stable environment in the study area.

3.16 POPULATION

The total population of the district is 904835 of which 795053 in rural and 109782 in urban area. The urban population of entire Bongaigaon town area is 825441 of which 60327 is municipal area, 15601 in Rly colony and 6613 in BRPL township.

The population trend of the Bongaigaon town is mentioned in the Table 3.2 as per the census report; 2001 [90].

Table 3.2 : Population of Bongaigaon town

Area	Year		
	1971	1991	2001
Bongaigaon (municipal area)	13907	35655	60327
New Bongaigaon Rly colony	11043	13252	15601
BRPL, Township	-	-	6613
Total	24950	48907	82541

Source: Statistical Hand Book, 2004

3.17 ORIGIN OF TUNIA RIVER

The Tunia river is a tributary of Champamati river. The river is originated from the low lying area which name is Bher Bher beel and located back side of the BRPL complex. Basically, it interconnect with the under ground stream which is flows from the Aie river. The distance of the Aie river and the source of Tunia river is about 4 km away and the area of Bher Bher beel is about 0.3923 km^2. Probably, the river Aie is the origin source of Tunia river through the subterranean flow. In flood season, the Aie river is directly linked with the Tunia river through the Bher-Bher beel.

The Tunia river flows the western side of the Bongaigaon town near BRPL complex and moves through the cultivated land of Kukurmari village up to New Bongaigaon. At New Bongaigaon, the Tunia river crosses the railway line and flows through village such as Senapara, Mulagaon, Jalkajahar, Boitamari and Silibari. After flowing about 35.3 km from the Bher-Bher beel, Dhaligaon, the Tunia river confluenced with the Champamati river at Champamukh which is 10 km away from the river Brahmaputra. The figure 3.1 shows the location of the Tunia river and catchment area.

The details of the Tunia river is mentioned below.

i) Length : The length of the river is 35.30 km

ii) Breadth : About 5.30 meters at source, Dhaligaon and 40 meters at Champamukh before confluencing with the Champamati river.

iii) Depth : The average depth of the river is 1.5-2 meters.

iv) Slope : The slope of the river is 1:800

v) Flow rate : The average flow rate is 1.40 m^3/ sec in winter and 7.8 m^3/sec in summer.

vi) Catchment area :The catchment area of the river is mentioned in the Table 3.3.

Table 3.3 : Catchment area of the Tunia river

Sl. No.	Nature of catchment	Area (km^2)
1	Bhairab reserved forest	18.534
2	Nakati reserved forest	15.763
3	Grazing land	36.780
4	Agricultural land	30.00
5	Bongaigaon town	4.35
6	Railway colony	3.00
7	BRPL complex	3.20
8.	Village residential	10.00
	Total	**121.627**

3.18 FLOOD HAZARD

The Tunia river always initiates flood hazard problems in the down stream area and damages agriculture and other lifes in the summer.

3.19 SUMMARY

The natural environment is most important for a stable eco-system. The mutual inter dependence of all the living system are influencing by the natural environment. The temperature and rainfall are most driving force for maintaining a stable ecosystem. The study area experiences a subtropical humid climate. Therefore, . the pollution problem is gradually diminishing due to favourable natural environment.

The Tunia river is a small tributary of the Champamati river. The water flow is minimum in winter and maximum in summer season. The river always creates flood hazards in the down stream area at Champamukh and damages agriculture and lifes.

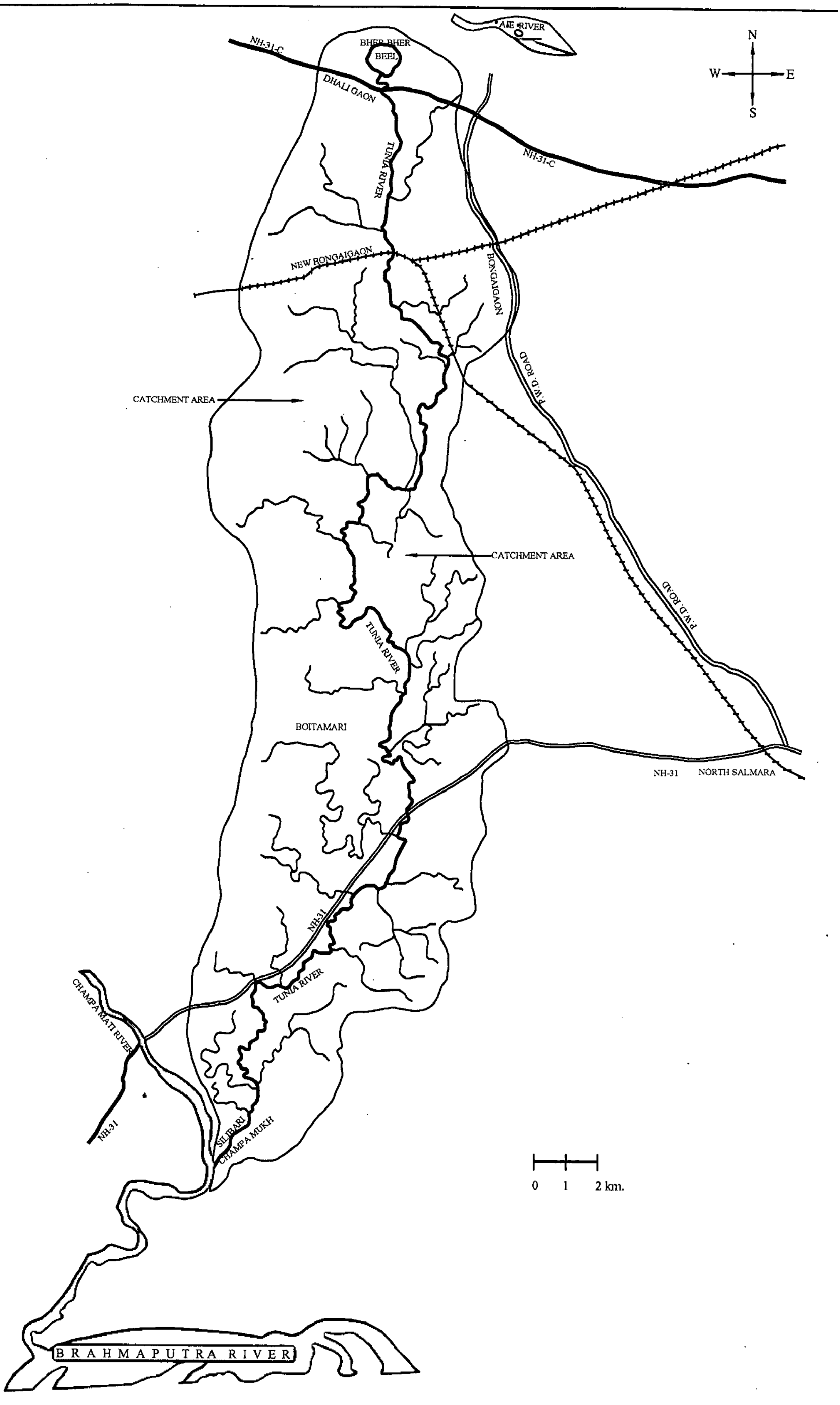

FIG. 3.1 : Location of the Tunia river and catchment area

POLLUTION OF TUNIA RIVER

4.1 GENERAL

The water of the Tunia river is gradually deteriorated due to industrialization and urbanization of Bongaigaon town. Basically, water is polluted by industrial and domestic activities. The industrial pollution is more complex than the pollution due to urban activities. The pollution loads are concentrated in between BRPL out let to Bongaigaon town area along the flow path of Tunia river.

4.2 SOURCES OF POLLUTION

The sources of pollution of the Tunia river can be classified as;

1. Point sources
2. Non point sources.

4.2.1 Point Sources

Point sources involves discharge or wastes from identifiable points. The sources are :

1. **Industrial plants :** Industries such as Bongaigaon Refinery and Petrochemicals Ltd., C&W Workshop, N.F. Railways, Brahmaputra Carbon Ltd., Assam Chemical Industries, North East Gases Pvt. Ltd., Bongaigaon Roller Flour Mills and other small industrial units which discharges their effluents directly into the Tunia river.
2. **Drainage system :** The sewage from New Bongaigaon Railway colony and Bongaigaon municipal area are going to the Tunia river without any treatment. The domestic sewage of BRPL township is discharged

through the refinery effluent after treatment at Dhaligaon. The waste water of New Bongaigaon Rly. station is also discharged into the Tunia river along with waste water from the C&W Workshop, N.F. Rly. All domestic sewage are concentrated from Railway colony to Bongaigaon town area in the Tunia river. Consequently, this river area is highly polluted by the sewage water.

3. **Storm water run off :** The storm water confluence directly with the Tunia river water through the drain. It increases the siltation and BOD load in the Tunia river.

4.2.2 Non Point Sources

Non point sources involves the diffuse discharge wastes from land run off, atmospheric washout and other sources that are difficult to identify and control. Considering to the Tunia river, the sources are :

1. **Urban storm water run off :** This source leads to siltation and organic pollution load in the river water.

2. **Run off of chemical fertilizers, pesticides and saline irrigation water from crop land :** This sources are limited with respect to other sources because of very less amount are used such types of chemicals. Besides, about 30 square km area are used as cultivated land out of total catchment area (121.627 square km) of the Tunia river. Therefore, their adverse affect can be ignored in comparison to the other sources.

Basically, non point sources of pollution are widely spread out, difficult to identify and hard to control.

4.3 POLLUTION BY INDUSTRIES

The Tunia river is polluted by the industrial units and these sources dominated major portion of pollution load in respect of the Tunia river. The following industrial units are considered as a polluting units in regards of the Tunia river.

1. Bongaigaon Refinery & Petrochemicals Ltd (BRPL).
2. Brahmaputra Carbon Ltd.
3. Assam Chemical Industries.
4. North East Gasses Pvt Ltd.
5. Birjhora Tea Estate.
6. Bongaigaon Roller Flour Mills.
7. C&W Workshop, N. F. Railways.
8. New Bongaigaon Railway Station.
9. Hospital Waste Water.
10. Automobile Waste Water.
11. Industrial Estate.

4.3.1 Bongaigaon Refinery and Petrochemicals Ltd. (BRPL), Dhaligaon, Bongaigaon

Bongaigaon Refinery and Petrochemicals Ltd. is the main source of pollution of the Tunia river. BRPL was established on 20th February, 1974 at Dhaligaon, about 5 km away from the Bongaigaon town. About 2.35 million tones of crude oil are refining in a year. The unit produces 29000 tonnes of Paraxylene, 45,000 tonnes of DMT and 30,000 tonnes of PSF in a year.

The unit uses the main raw materials are crude oil 2350000, Methanol 920, Ethylene glycol 1100, and Chlorine 32.50 M.T. in a year.

The BRPL also uses about 32400m^3 of water in a day and drawn from the ground water sources. The unit generates 9960m^3 of effluent from their operation. BRPL discharges about 8580m^3 of effluent in a day into the Tunia river after treatment in their effluent treatment plant.

4.3.2 Brahmaputra Carbon Ltd., Dhaligaon, Bongaigaon

This is a calcined petroleum coke producing unit. The unit uses 218 MT of raw petroleum coke in a day and also uses 40 liters of diesel in a day. The unit produces about 160 MT of calcined petroleum coke in a day. The unit uses 120 m^3 of water in a day from the ground water sources.

Brahmaputra carbon Ltd generates 5m^3 of effluent in a day and discharges to the Tunia river after mixing with lime and bleaching powder. Basically, the effluent is domestic nature.

4.3.3 Assam Chemical Industries, Dhaligaon, Bongaigaon

This is a pesticide formulation unit which is established in 1970.

The industry uses 1.96 MT lindane tech., 4.75 MT malathion tech. and 0.05 MT endosuffan tech., in a day. The unit also uses required amount of china clay, soap stone, solvent and detergents. The unit produces 55.90 MT of lindane powder 1.3 %, 75.90 MT of malathion powder 6.5 %, 0.843 KL of malathion EC (liquid) 5%, 0.131 KL of endosuflan EC (liquid) 35% and 2.03 KL of malathion EC 50%.

Water is used only for drinking purposes and no water is used for the process. Though the unit does not discharge any effluent but emitting the storm water from their premises is a serious matter for the water system of the Tunia river because of some contaminants may be carried away by the storm water along with the domestic sewage in a rainy season.

4.3.4 North East Gases Pvt. Ltd., Dhaligaon, Bongaigaon

The unit was established in 1993 at Dhaligaon, Bongaigaon. The unit uses 187 MT of calcium carbide and 500 litres mobile oil in a month.

The unit produces 4228.17 m^3 acetylene gas, 21040.85 m^3 oxygen gas and 386.59 m^3 nitrogen gas in a month.

The unit uses 12 m^3 of water in a day from the deep tube well. The waste water about 10 m^3 in a day is discharged through a pucca drain which is connected with the lime chamber and deposited in a low laying area and ultimately which is going to the Tunia river after mixing with lime.

4.3.5 Birjhora Tea Estate, Bongaigaon

The tea estate was set up at Bongaigaon in 1928 and uses 307012 kg of green leaf in a month. The unit produces 1 lakh kg of tea in a month. The unit uses 24 m^3 of water in a day from the ground sources. The tea estate generates 3 m^3 of effluent in a day and ultimately which goes to the Tunia river through the municipal drain.

4.3.6 Bongaigaon Roller Flour Mills, Bongaigaon

The unit produces the atta and flours as per demand of the area. The mill uses about 36.34 m^3 of water in a day. The mill generates 33.68 m^3 of effluent in a day and discharges into the municipal drain after addition of lime which is ultimately going to the Tunia river.

4.3.7 C&W Workshop, N.F. Railways, New Bongaigaon

The unit is commissioned in 1965 for repairing and build up of railway coaches. The unit uses 42.52 MT of MS plate, 2 MT of Ingot and 5.890 m^3 of various paints in a month.

The unit uses 1726.34 m^3 of water in a day. The workshop discharges about 48 m^3 of effluent into the Tunia river in a day after mixing with lime and other chemicals.

4.3.8 Railway Station, New Bongaigaon

The New Bongaigaon Railway Station is most important station cum junction in Assam. All trains are stopping for the passenger and subsequently cleaning operation is done in the station area. Night soil, urine and other organic matters are discharged to railway tracks and station area which ultimately goes to the Tunia river.

The station uses 300 m^3 of water for cleaning and drinking purposes in a day. About 150 m^3 of waste water is discharged into the Tunia river through their own nullah in a day.

4.3.9 Hospital Waste Water

There are three hospitals, eight nursing homes and twenty patholabs are performing their functions in the entire Bongaigaon town.

The total bed of said nursing home and hospitals are about 1000. Therefore, nearly 340 m^3 of water is used and 270 m^3 of hospital waste water is released into the Tunia river.

4.3.10 Automobile Waste Water

There are 15 numbers of motor garages and 3 numbers of servicing centre which are operating in the Bongaigaon urban area. Consequently, about 60 m^3 of waste water in a day is discharged to their respective drain which is ultimately going to the Tunia river.

4.3.11 Industrial Estate, Bongaigaon

There are 5 plastic industries and few small industrial units in the estate but their discharge amount is very negligible. About 10 liter of waste water is discharged by each plastic unit and other industries also show similar nature in respect of such effluent discharge.

4.4 POLLUTION BY DOMESTIC SOURCES

Both urban and rural area discharges waste water into the neighbouring area ultimately which goes to the Tunia river.

4.4.1 Rural Area

There area about 25 thousand people live in and around the Tunia river along its 30 km distance of flow path in the rural area. Depending upon the habits and standards of living of the people, about 75 liter of water is used by a person in a day. Due to large disposal area and diverse nature, nearly 20 % of its use of water is going to the Tunia river as a sewage water. Consequently, about 375 m^3 of sewage water is reached into the Tunia river in a day against 1875 m^3 use of water. The adverse affect of this sewage water is negligible due to its diverse nature and favorable natural factors of self purification process of the Tunia river (as referred from the project report, studies on the sources of pollution in Tunia river, August, 2005) [20].

4.4.2 Urban Area

The total population of Bongaigaon municipal area and New Bongaigaon Railway colony is 75928 of which 15601 of Railway colony and 60327 of Bongaigaon municipal area. The population of 6613 of BRPL township is not considered because their sewage water is discharged through the BRPL's main out let.

About 11390 m^3 of water is used per day for domestic purposes as based on of a gross of per capita average demand of 150 lpcd. Consequently, about 9112 m^3 of waste water per day is discharged into the Tunia river as a result of better drainage system on the basis of approximately 80% of domestic uses water passes out as waste water (as referred from the project repot). Therefore, the water environment of the Tunia river has been gradually converted into sewage environment.

4.5 POLLUTION BY AGRICULTURAL CHEMICALS

The fertilizers and agricultural chemicals such as pesticide, weedicide and insecticides may be ignored along the flow path of the Tunia river in rural area under the catchments area of the Tunia river. There are no pesticide, weedicide and insecticide are found in the water analysis of the Tunia river. Besides, use of fertilizers is also very less with respect to the other parts of the country. Average 8.6 kg of fertilizers are used in a bigha (0.13387 hectares) in the state which is very small quantity with compare to the required amount of the soil. The use of fertilizers in the agricultural land of the catchments area of Tunia river is more less than the state average because of this area is less agricultural developed with respect to the other parts of the state. Therefore, the adverse affect of fertilizers and agricultural chemicals can be ignored with compare to the water pollution load in the Tunia river.

4.6 ORGANIC POLLUTION

All the sources carries pollutants as organic nature into the Tunia river. Both industries and domestic activities are responsible for polluting the Tunia river. Basically, industrial pollution are more Complex than the domestic pollution. The sources of organic pollution are as :

4.6.1 Domestic

The organic load is directly proportional to the population. Urban communities contributes the largest share of organic pollution load than the rural communities. The sources of rural and urban area for the Tunia river are considered as:

4.6.1.1 Rural area

The BOD contribution of rural area has been considered as 15 grams per person in a day into the Tunia river due to the divergence nature of disposal system. This assumption has been generally used to estimate pollution load in Brahmaputra river as referred from "The Brahmaputra Basin" which is published by the CPCB, October, 2000 [Assessment and development study of river basin series : ADSORBS/33/2000-2001] [14].

There are 25 thousands people live in rural area of the Tunia river and the BOD load is contributed by the rural people to the Tunia river for about 375 kg in a day. Again this organic load is distributed as a divergent nature and easily removed their adverse affect by the self purification process of the river.

4.6.1.2 Urban area

The total population of Bongaigaon town is 75928 and contributes 2278 kg of BOD load in a day into a the Tunia river. This amount concentrates as a point source in a close area of Tunia river. Consequently, it affects the entire ecosystem of the Tunia river.

4.6.2 Industries

The industrial units discharges organic load through its effluents. The total quantity of organic load discharged into the Tunia river is shown in the Table 4.1.

Table 4.1. Permissible organic pollutional load of industrial units before confluence with the Tunia river as per (CPCB)

S. No.	Name of industries	Dischargeof effluent (m^3/day)	BOD permissible limit (mg/l)	BOD Kg/day	COD permissible limit(mg/l)	COD (kg/day)
1.	BRPL	8580	15	128.70	250	2145
2.	C&W workshop and New Bongaigaon Railway station	198	30	5.94	250	49.50
3.	Brahmaputra Carbon Ltd	5	30	0.15	250	1.25
4.	North East Gases Pvt. Ltd.	10	30	0.30	250	2.50
5.	Bongaigaon Roller Flour Mills	33.68	100	3.37	250	8.42
6.	Birjhora Tea Estate	3.0	30	0.09	250	0.75
7.	Hospital waste water	270	30	8.10	250	67.50
8.	Automobile service centre	60	30	1.80	250	67.50
	Total	**9159.68**		**148.45**		**2289.92**

Source: Pollution Control Board, Assam, 2004-2005.
Note: Permissible limit as per CPCBs for various water uses are given in the table 7.5 and 7.6.

From the above table, it is seen that the Tunia river receives about 2439 kg of organic load per day from the industrial units which 149 kg are easily bio degradable and 2290 kg are less bio degradable.

4.7 OIL POLLUTION

The Tunia river receives about 27.45 kg of oil and grease in a day from the BRPL. The river also receives near about 1.621 kg/day of phenolic compounds from the BRPL. Both pollutant are important and affect adversely on the Tunia river ecosystem. BRPL discharges both parameters under permissible limit but water quality of the river is gradually deteriorated due to this pollutants.

4.8 SUMMARY

The Tunia river receives the organic pollution load from the industrial unit as well as domestic sources. Industrial units discharges about 2439 kg and domestic sources releases about 2653 kg of organic pollution load per day into the Tunia river. Considering the chemical nature,2802 kg are easily biodegradable and 2290 kg are less bio-degradable. Oil pollution is another factor for Tunia river ecosystem. It affects adversely on flora and fauna of the Tunia river.

Basically, the effects on water by industrial units are more complex than the domestic sources.

CHAPTER - 5

METHODOLOGY

5.1 INTRODUCTION

Indiscriminate disposal of industrial effluent and domestic sewage in rivers has led to serious river pollution in India. Effective monitoring of parameters is an important initial step in abatement of river pollution. The monitoring techniques can be classified as conventional, automatic recording and remote sensing techniques. The Tunia river has been monitored conventionally for 4 seasons. Ten sampling stations are selected after conducting the reconnaissance survey of the river. Samples were collected on season wise and analysed for the required parameters.

5.2 RECONNAISSANCE SURVEY

The reconnaissance survey has been performed before selecting the sampling station, sampling schedule and frequency of sampling. The following informations are collected through the reconnaissance survey:

1. The industrial effluents are confluenced with the Tunia river water.
2. The domestic waste water is directly discharging into the river.
3. Three crematorias are used near New Bongaigaon railway station.
4. The waste water including urine, nutshell and solid wastes of the New Bongaigaon railway station are directly discharging into the river.

5. River water is being utilized for agricultural purposes at Boitamati area.

5.3 CRITERIA FOR SELECTION OF SAMPLING STATION

The sampling station should be located to provide an realistic description of existing water quality. Besides this, the sampling stations should be selected to maximize the ease of sampling. The actual location of sampling station is primarily depend on the physical situation.

The selection of sampling station or sampling points depends on various objectives of water quality monitoring program such as;

1. Too near or too far distant of sampling points should be avoided for chemical analysis in respect of the site of water sampling.
2. The sampling points should be moved upstream of the discharge point or sufficiently down stream to ensure that mixing has taken place.
3. Impact of human activities upon the quality of water and suitability for use.
4. The sources and pathways of pollutants.
5. Influence of polluted and unpolluted water on distribution, density and community structure of the biota.
6. It should be accessible in all seasons of the year.
7. It should have proper mixing of pollutants thus representing water quality of river at that particular stretch.
8. Facilities to take water samples are provided for better collection of samples from the water bodies.

9. Stagnant zone of the surface water should be avoided for bacteriological samples.

10. Self purification capacity of the water body.

11. The quality of water in its natural state which might be available to meet the future need.

12. It should effect the quality of water..

    1. Before drains from the city discharge.
    2. Inside city where maximum pollution occurs and
    3. After the river leaves the city area.

Based on the above criteria, ten numbers of sampling stations were identified along the stretch of the Tunia river and the outfall of BRPL and other industrial units along with sewage water of railway station, colony and Bongaigaon including before and after confluencing with the Champamati river.

5.4 SELECTION AND DESCRIPTION OF SAMPLING STATIONS

The objective of sampling is to collect the water samples form the river at the sampling station. The following sampling stations of the Tunia river are considered on the basis of required criteria's:

1. **Sampling station (SS_0):** This sampling station is selected at the source of the Tunia river, Dhaligaon before confluencing with the BRPL's effluent. The Tunia river is not received any effluent or sewage before this station.

2. **Sampling station (SS_1) :** This sampling station is located at the bridge of NH-31-C, Dhaligaon after confluence of BRPL's effluent and about 0.5 km away from the source of the Tunia river. This

sampling station is selected and recognized by the pollution control board, Assam.

3. **Sampling station (SS_2) :** The sampling station is located at Kukurmari at a distance of 0.5 km from the SS_1 and total distance of about 1 km from the source of the Tunia river after received effluents from the North East Gases Pvt Ltd (NEGPL) and Brahmaputra Carbon Ltd (BCL). Some sewage water from hotel and restaurants and waste water from motor garage are confluened with the Tunia river water before this sampling station.

4. **Sampling station (SS_3) :** The sampling station is located at New Bongaigaon at a distance of 2 km away from the SS_2 and about total distance of 3 km from the source of the Tunia river. The sewage water from the Railways colony area and effluent from Bongaigaon Roller Flour Mills (BRFM) are confluenced with the water of the Tunia river before this station. After confluence of proper mixing, the station is selected for ascertaining the quality of river water. Besides, the sewage water is also released from the hotel, restaurant, patholab, nursing homes etc in this area and ultimately reached to the Tunia river.

5. **Sampling station (SS_4):** This sampling station is located in New Bongaigaon which is near the railways bridge, at a distance of 0.5 km from the sampling station SS_3 and at about total distance of 3.5 km from the source. The sewage water from the New Bongaigaon railway station and effluent from the C & W

workshops are confluenced with the Tunia river water. Ashes of human bodies from three crematorias are mixed with the water of the Tunia river before the station.

6. **Sampling station (SS_5) :** This sampling station is located in Bongaigaon town which is at a distance of 1.0 km from the SS_4 and at about total distance of 4.5 km from the source of the Tunia river. Sewage water is mixed with the river water from the Bongaigaon town along with storm water is confluenced with the river water which flows through the agricultural area. Some small and thiny industrial units are located in and around the town area which contributes the pollutional load into the Tunia river. The dead animals such as cows, dogs and other carcassials materials are deposited near the bank of the river. Open faeces has been seen around the bank of the river.

7. **Sampling station (SS_6) :** This sampling station is located at the bridge of NH-31 which is about 19 km away from the SS_5 and at a total distance of about 23.5 km from the source of the Tunia river. Water is drawn from the river before this station by the lift pumps for irrigation in the Boitamari village.

8. **Sampling Station (SS_7) :** This station is located at Silibari which is at a distance of about 11 km from the SS_6 and at a total distance of about 34.5 km from the source of the Tunia river.

9. **Sampling Station (SS_8):** This sampling station is located upstream of confluence point of Tunia river with Champamati river

which is at Champamukh with a distance of 0.5 km from the SS_7 and at a total distance of about 35 km from the source of the Tunia river.

10. **Sampling station (SS_9)** : This sampling station is located downstream of confluence point of Tunia river and Champamati river which is at the distance of 0.8 km from the SS_8 with total distance of about 35.8 km from the source of the Tunia river.

The brief summary of sampling station and effluents or domestic sewage are confluenced with the Tunia river water before the respective sampling stations are tabulated in Table 5.1.

Table 5.1: Summary of sampling station

Sl. No.	Sampling station (SS)	Location	Distance from previous SS (km)	Distance from sources of Tunia river (km)	Confluence of effluent/ sewage before SS from
1.	SS_0	At source Dhaligaon	-	0	-
2.	SS_1	NH-31C, Dhaligaon	0.50	0.50	BRPL
3.	SS_2	Kukurmari	0.50	1.0	NEGPL & BCL
4.	SS_3	New Bongaigaon	2.0	3.0	Rly. colony & BRFM
5.	SS_4	Rly. Bridge, New Bongaigaon	0.5	3.5	New Bongaigaon Rly. station and C & W workshop
6.	SS_5	Bongaigaon	1.0	4.5	Bongaigaon town
7.	SS_6	NH-31, Boitamari	19.0	23.5	Village
8.	SS_7	Silibari	11.0	34.5	Village
9.	SS_8	Champamukh	0.5	35.0	Village
10.	SS_9	Champamukh, Champamati river	0.8	35.8	Tunia river

The location of sampling stations and industrial units are shown at the Tunia river in the Figure 5.1 and also shows the photographs of the said sampling stations in the Figure 5.2-5.11 accordingly.

5.5 TYPES OF SAMPLES

The samples must be representative in nature. The samples are generally of three types:

1. **Grab sample:** It is a sample taken at a sampling point and time. The sample is collected from the main current and 20 to 30 cm below the surface to avoid collection of scum. This sample may be taken to represent the water quality of the source.
2. **Composite sample:** It is a combination of equal volumes of a number of grab samples collected at the same location at different times. Composite samples may be required only in special cases for calculation of mass flux in rivers when the quality of water is suspected to change over short periods of time.
3. **Integrated sample:** It is a mixture of grab samples collected simultaneously at different locations across the width of the river or at different depth. The need for an integrated sample may occur for very wide and deep rivers where the quality of water may vary across its width and depth.

5.6 METHOD OF WATER SAMPLING

The method of water sampling mainly depends on the nature of analysis to be carried out. Analysis may be broadly divided into physicochemical, bacteriological and biological categories [97].

1. **Water samples for chemical analysis:** The water samples are collected from a depth of 20-30 cm from the river by the plastic containers of minimum 5 liter of capacity, provided with double cap device. The samples are collected up to the top, without leaving any space so as to prevent the premature release of dissolved gases during the transit period.
2. **Water samples of bacteriological analysis:** The water samples are collected from 30 cm depth of the river in properly sterilized neutral glass bottles of 120 ml capacity. The water sample is not collected up to the top of the glass bottles due to the survival of bacteria. The water sample are analysed within 24 hours of collection.
3. **Water samples of biological analysis:** The river water up to a depth of 10 cm are collected in wide mouth glass bolltes of 1 liter capacity and preserved by using 1ml of Lugol's solution. The collection of samples was done in the morning time. All the samples were brought to the laboratory and stored at 4°C in a refrigerator till the analysis was completed.
4. **Water samples of bioassay test:** The water samples of about 15 liter are collected from 20-30 cm depth of the river in a plastic container. Any floating matter should be avoided.

5.7 TIME INTERVAL BETWEEN COLLECTION AND ANALYSIS OF SAMPLES

Some parameters such as pH, temperature and dissolved oxygen are analysed on the spot as soon as the samples are collected.

The samples collected for bacteriological parameters are analysed within 24 hours of their collection.

The samples for the identification and evaluation of algae are preserved by adding lugol's solution or 4% formalin solution at the time of sample collection.

The water samples for the bioassay test is used within 12 hours of their collection from the river.

5.8 SAMPLING PROGRAMME

Water samples are collected and analysed in the 4 seasons for this study. Grab samples were collected from the respective sampling stations since time constraints and shortage of manpower did not permitted to collection of integrated or composite samples from the river. Besides, this is a small river and pollution has not been changed abruptly for a long period. Therefore, one or two grab samples were collected form the respective sampling station in each month at different date of the season. The following sampling schedule is mentioned in Table 5.2.

Table 5.2: Sampling schedule for the study period

Sl. No.	Season	Years	Month
1.	Monsoon	2005	July
2.	Post monsoon	2005	October & November
3.	Winter	2006	January & February
4.	Premonsoon	2006	April

(The analysis results of monsoon period is referred form my project report which has already been done in July, 2005).

5.9 EXPERIMENTAL WORKS

Physicochemical and bacteriological parameters were evaluated and algal identification and bioassay test are performed according to the methods specified in "Standard Methods for the Examination of Water and Wastewater" (APHA-AWWA-WPCF-1995) [8]. The techniques, instruments and principles involved in arriving at different water quality parameters are tabulated in Table 5.3 (Mathur, 1984 and Standard Methods, 1995) [56, 28].

Table 5.3 : Summary of analytic method

Sl. No.	Parameters	Principles	Instrument / Technique used
1	Temperature	Metric	Thermometer.
2	Turbidity	Photometric	Nephlometer or turbidity meter.
3	Dissolved solids	Gravimetric	Evaporation of filtrate (Whatman paper no. 44) at 103^0-105^0C
4	Total solids	Gravimetric	Evaporation in oven at 103^0C-105^0C hrs.
5	Total suspended solids	Gravimetric	Difference of residue of total solids and residue of dissolved solids in muffle furnace at 600°C in 20 minutes.
6	Specific conductance	Electrometric	Digital conductivity meters
7	pH	Electrometric	Digital P^H meter
8	Dissolved oxygen	Volumetric or Electrometric	Winklers method, Digital D. O. meters
9	BOD	Volumetric	Dilution technique and keeping the sample at 20°C for 5-days followed by winkers method.
10	COD	Volumetric	Dichromate digestion method
11	Ammonical nitrogen	Calorimetric	U.V. spectrophotometer, Nesselerization
12	Nitrate	Calorimetric	U.V. Spectrophotometer, Phenoldisulphonic acid method
13	Total Nitrogen	Calorimetric	Kjeldahal method, U.V. Spectrophotometer
14	Sulphate	Volumetric	Precipitate as $BaSo_4$
15	Sulphide	Volumetric	Methylene blue method
16	Phosphate	Calorimetric	U.V. Spectrophotometer, $Sncl_2$ method
17	Oil & Grease	Gravimetric	Extraction method
18	Phenols	Calorimetric	U.V. Spectrophotometer
19	Fluoride	Electrometric	Ion selective electrode
20	Chloride	Volumetric	Titrimetric method using $AgNo_3$
21	Total coliform	MPN-index	Mc. Concey's browth at 35°C for 48 hrs
22	Faecal coliform	MPN-index	Mc. Concey's browth at 44°C for 48 hrs
23	Algae	Enumeration	Microscopic field by lackey's drop count method
24	Mortality of fish	Glass aquariums	Bioassay test

5.10 SUMMARY

Effective monitoring of parameters is an important initial step in abatement of river pollution. The selection of sampling satiations and collection of samples are the most important function for a river water quality assessment program. The samples should be representative of the water body under examination and to avoid accidental contamination of the sample during the time of collection because the interpretation of results and recommendations for treatment are all based on the analysis report.

Oil & grease and phenol are most important pollutants for the Tunia river which is entered into the river through the BRPL's effluent. Extraction method for oil & grease and U.V. spectrophotometer meter for phenol are used for exact estimation of pollutants.

Percentage of mortality of fish or toxicity test through fish bioassay is used for detection, evaluation and abatement of water pollution. Microscopic enumeration of algae indicates the polllutional status of the river.

Therefore, the selection of method or technique used are most important for detection and evaluation of pollutants which ultimately helps to initiate to abatment of river pollution.

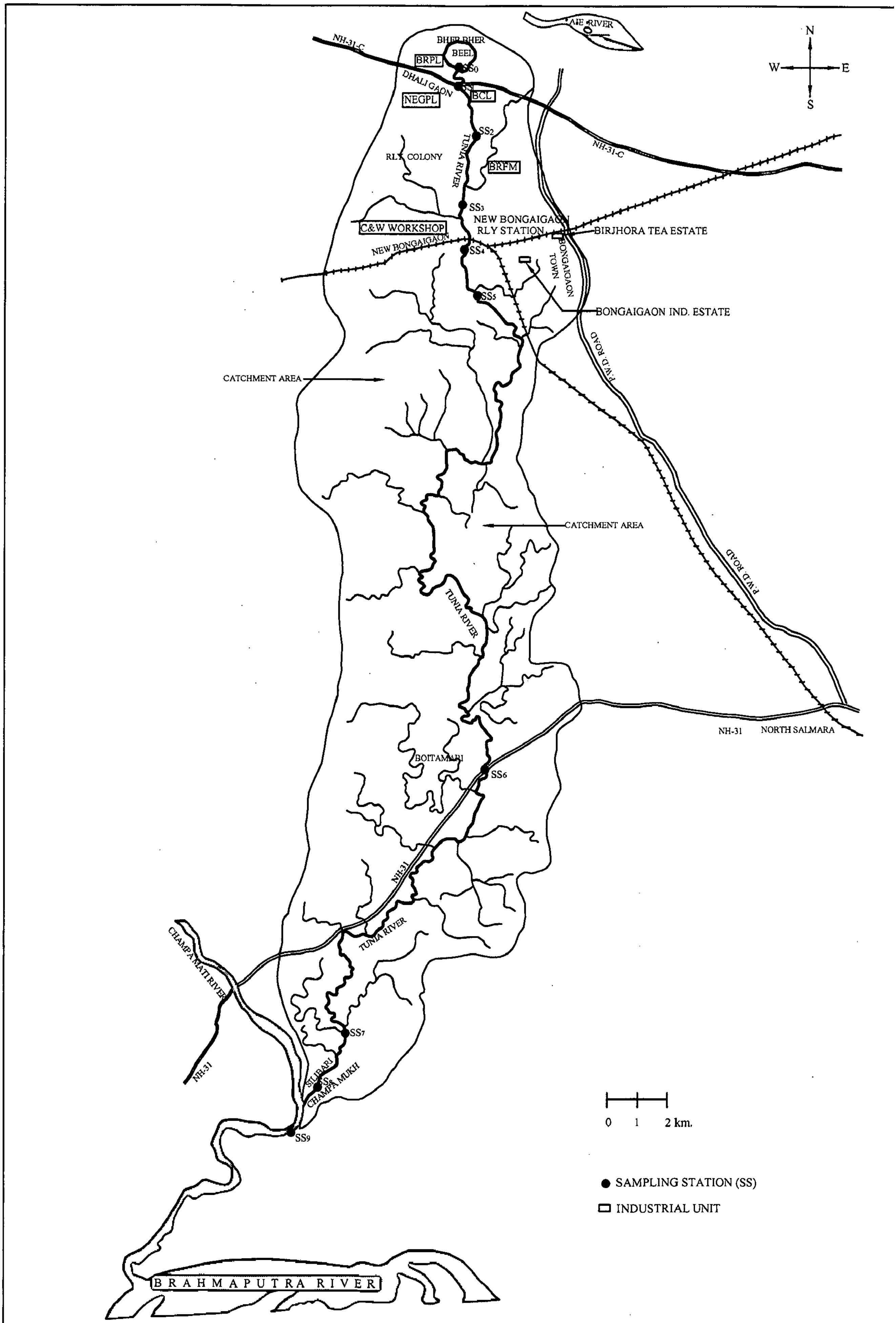

FIG. 5.1: Location of the sampling stations and industrial units at the Tunia river

The photograph of the approximate location of the sampling stations are shown in the following Figure 5.2 - 5.11

FIG. 5.2 : Sampling station (SS_0), Dhaligaon.

FIG. 5.3 : Sampling station (SS_1), Dhaligaon.

FIG. 5.4 : Sampling station (SS_2), Kukurmari.

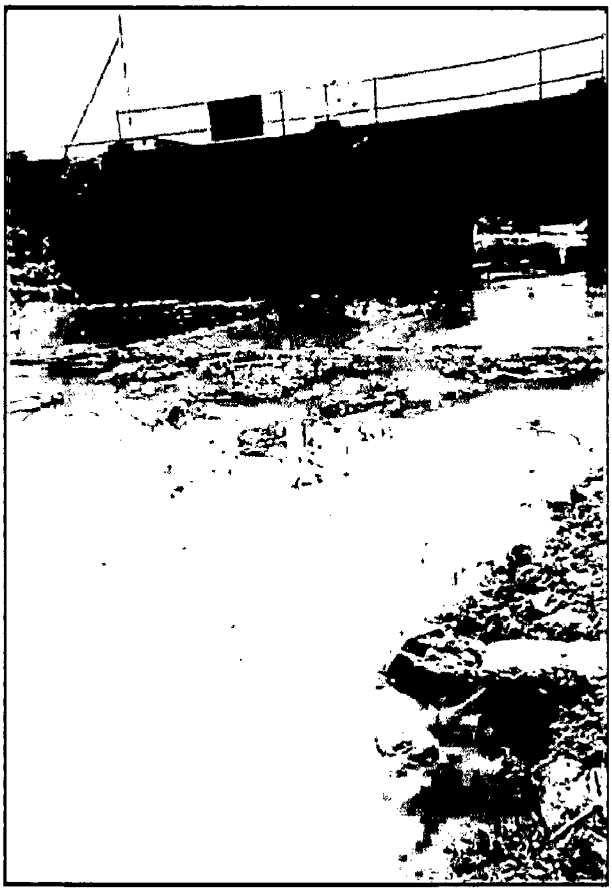

FIG. 5.5 : Sampling station (SS_3), New Bongaigaon.

FIG. 5.6 : Sampling station (SS_4), New Bongaigaon.

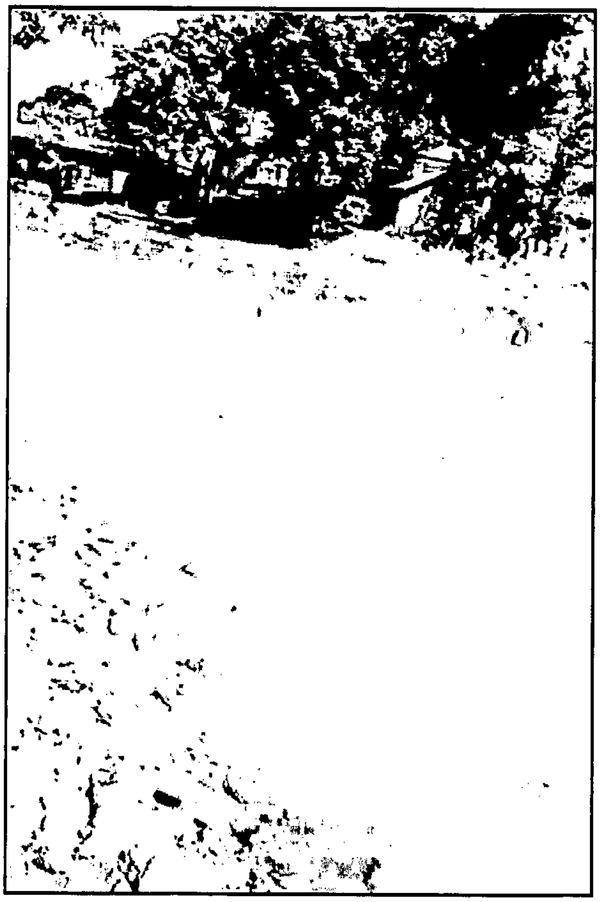

FIG. 5.7 : Sampling station (SS_5), Bongaigaon.

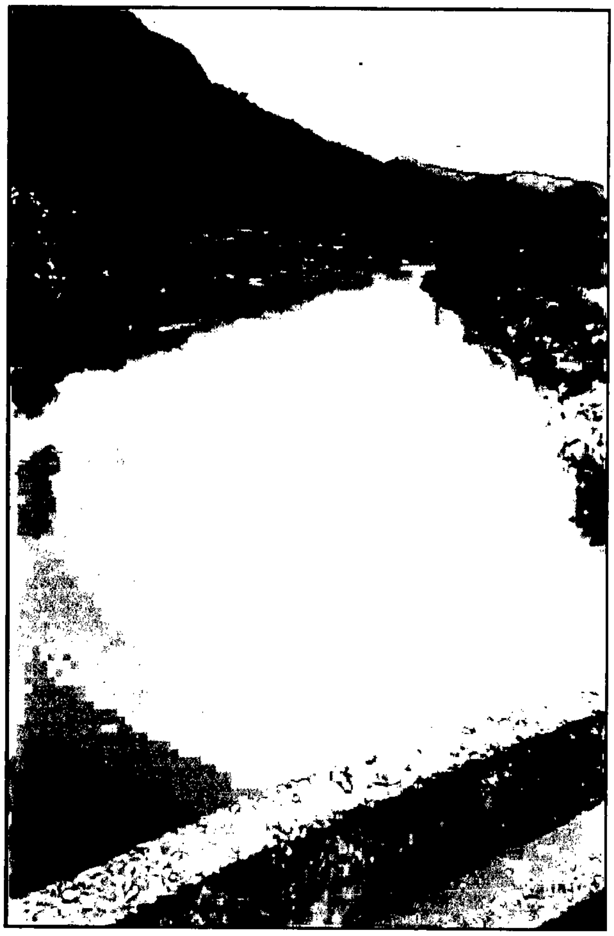

FIG. 5.8 : Sampling station (SS_6),
N H - 31, Boitamari.

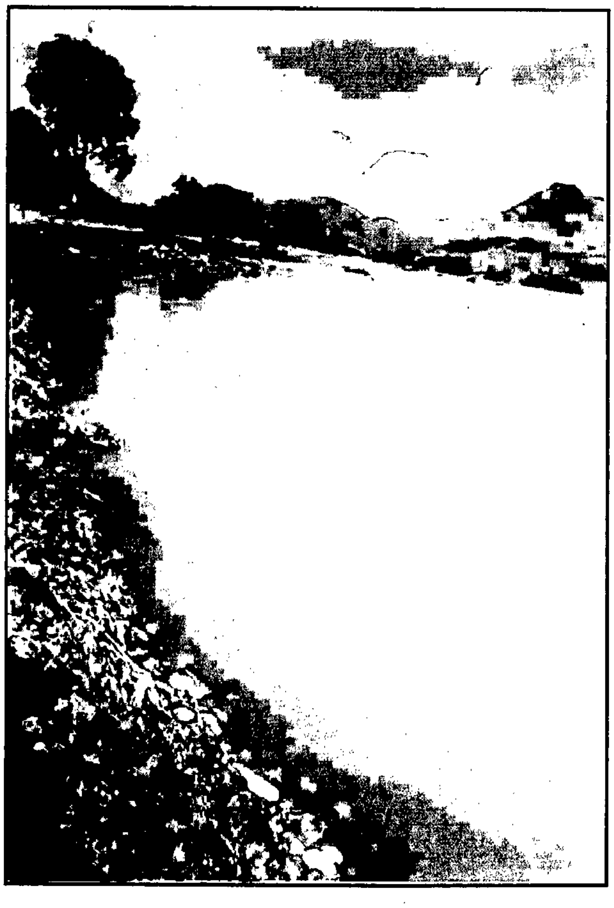

FIG. 5.9 : Sampling station (SS_7), Silibari.

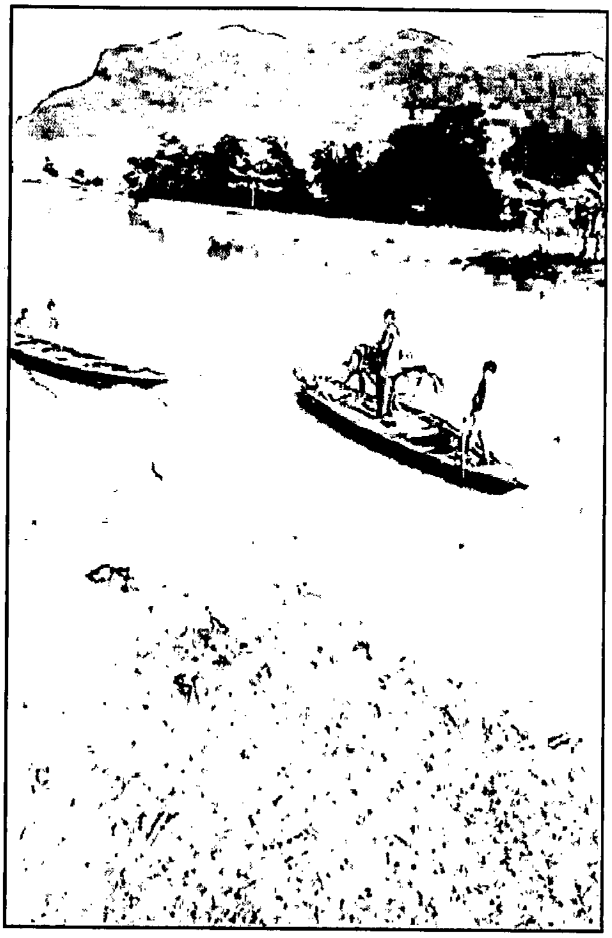

FIG. 5.10 : Sampling station (SS_8), Champa mukh.

FIG. 5.11 : Sampling station (SS_9), Champa mukh.

RESULT AND ANALYSIS

6.1 GENERAL

The water analysis is most important part for ascertaining the pollution level in a water body. The water quality analysis, algal analysis and bioassay test are essential for measuring the pollution level of the river. Only one type of analysis is not possible to ascertain the exact pollutional level of a water system.

Water quality analysis, algal analysis and identification and bioassay test has been performed in the study period. Besides, effluents of various industries such as BRPL, BCL, NEGPL, and domestic sewage water of Railway colony, Railway station and Bongaigaon town area are also analysed for the necessary parameters.

Algal analysis has been done for the identification of the algal species at the various sampling stations of the Tunia river for ascertain the water quality of the river.

Fish bioassay test is performed for the fish mortaility and survival rate of fish in order to determine the level of pollution in the river water.

6.2 WATER QUALITY ANALYSIS

The water of the Tunia river are monitored for the physicochemical parameters such as physical, organic, mineral and other inorganic parameters and bacteriological parameters in monsoon, postmonsoon, winter and premonsoon. Nine sampling stations at the Tunia river and one at the Champamati river after confluence of the Tunia river are selected for analyzing the water quality parameters. The water of the Champamati river before confluence of the Tunia river is also analysed for the required parameters.

The effluents of various industries such as BRPL, NEGPL, BCL, and C&W workshop has been analysed for the physicochemical and bacteriological parameters. Similarly, the sewage water of Railway colony, New Bongaigaon Railway station and Bongaigaon town area are also analysed during the monsoon, postmonsoon winter and premonsoon.

6.2.1 Monsoon

Heavy rainfall has been occurred in Assam in June and July, therefore, the pollution problem of the Tunia river is not severe due to dilution in river water of the Tunia river. Two water samples in July, 2005 are collected and analysed at each sampling station of the Tunia river and two water sample of Champamati river before and after confluence of the Tunia river is also analysed for the required parameters.

Besides, the effluents of BRPL, NEGPL, BCL and C&W workshop and sewage water of the Railway colony, New Bongagaon Railway station and Bongaigaon town are analysed accordingly.

The detail of average water quality of physicochemical and bacteriological parameters at the various sampling stations of the Tunia and Champamati river are tabulated against the effluents and sewage water quality of the various units in the Table 6.1 for the monsoon period.

The brief average water quality of the Tunia and Champamati river at the various sampling stations are summarized in the Table 6.2 for monsoon.

Table 6.1: Water quality of the Tunia and Champamati river against the effluents and sewage water of the various units, monsoon, 2005

S.No.	Sampling stations	Conflunce from	pH	Temp. °C	Turb NTU	DO mg/l	BOD mg/l	COD mg/l	TKN mg/l	Oil & Grease mg/l	Phe. Comps mg/l	Sulphide mg/l	Sulphate mg/l	Chloride mg/l	Fluoride mg/l	Phosphate mg/l	Nitrate mg/l	Amm. nitrogen mg/l	TDS mg/l	TSS mg/l	Total coliform MPN/100	Faecal coliform MPN/100
1	SS_0		7.30	26.0	13.80	6.70	2.10	11.00	1.85	-	-	0.05	0.05	12.80	0.05	3.00	0.08	0.03	95.10	19.00	10,300	800.00
2		BRPL	6.95	28.50	20.50	4.74	8.77	42.10	4.45	3.20	0.189	0.10	32.60	22.20	0.101	0.53	2.90	3.90	400.00	19.20	-	-
3	SS_1		7.31	26.50	15.60	4.81	8.60	41.22	3.52	3.10	0.188	0.099	18.50	22.10	0.10	0.75	0.85	2.50	172.50	19.90	2,500.00	400.00
4		NEGPL	8.95	28.50	16.30	5.10	16.00	80.00	3.43	-	-	0.10	17.50	33.00	0.10	-	0.90	2.40	183.00	81.00	-	-
5		BCL	7.85	24.50	16.90	4.90	4.30	51.20	4.51	-	0.186	0.08	20.30	21.50	0.08	-	0.75	2.63	144.00	44.10	-	-
6	SS_2		7.32	26.00	17.20	4.25	8.62	41.30	3.55	3.09	0.187	0.098	19.50	22.20	0.099	0.72	0.83	2.45	166.30	20.30	3,000.00	500.00
7		Rly. Colony	7.20	27.00	50.10	2.50	100.00	175.00	4.80	0.155	0.08	0.10	26.30	35.50	0.06	1.30	3.50	1.85	205.30	100.00	160,000.00	64,000.00
8	SS_3		7.25	26.30	26.30	3.50	24.60	64.70	3.82	2.55	0.154	0.098	20.10	24.45	0.082	0.81	1.20	2.10	185.30	23.23	120,000.00	32,500.00
9		C&W work shop & New Bon.Rly. Station	7.90	30.00	29.30	2.90	45.50	100.00	4.10	5.50	0.05	0.10	22.30	38.00	0.09	0.89	1.50	0.92	181.50	100.00	63,000.00	10,000.00
10	SS_4		7.30	26.50	26.90	3.40	25.10	65.40	3.90	2.70	0.152	0.098	20.60	24.70	0.082	0.85	1.35	1.75	185.80	24.62	82,000.00	28,500.00
11		Bongaigaon town	7.10	27.10	27.20	3.00	95.00	172.00	4.10	0.10	0.07	0.10	21.30	36.00	0.10	1.30	2.40	1.36	191.20	110.00	75,500.00	42,000.00
12	SS_5		7.20	26.80	27.80	3.20	53.10	108.00	3.95	1.70	0.10	0.097	21.80	29.20	0.089	0.91	1.67	1.54	187.40	55.00	780,000.00	31,500.00
13	SS_6		7.25	26.30	31.50	4.20	14.20	52.20	2.91	1.45	0.10	0.096	20.10	26.30	0.089	0.82	1.10	1.25	155.50	42.30	58,000.00	19,500.00
14	SS_7		7.20	26.00	37.90	7.10	12.20	28.40	2.65	1.20	0.095	0.094	16.50	23.20	0.087	0.69	0.55	0.90	105.70	31.40	50,000.00	13,300.00
15	SS_8		7.30	25.50	39.50	7.90	3.30	20.10	1.55	1.00	0.09	0.092	11.50	21.20	0.088	0.50	0.30	0.41	84.20	20.00	46,000.00	12,500.00
16		Champamati river before confluence	7.10	24.50	31.20	8.33	1.00	3.58	0.90	0.90	-	0.10	8.50	7.21	0.10	0.01	0.06	0.06	98.00	4.50	225.00	90.00
17	SS_9	Champamati river after confluence	7.15	24.80	35.60	8.25	1.20	3.82	1.25	1.00	0.50	0.10	10.10	7.25	0.10	0.15	0.10	0.20	90.30	12.90	12,500.00	1,150.00

Table 6. 2: Water quality of the Tunia river at vairous sampling stations in monsoon, 200

S.No.	Parameters	SS_0	SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_7	SS_8	SS
A	**Physical Parameters**										
1	pH	7.3	7.31	7.32	7.25	7.30	7.20	7.25	7.20	7.30	7.
2	Temperature (^{0}C)	26.0	26.5	26	26.30	26.50	26.80	26.3	26.0	25.5	24.
3	Turbidity (NTU)	13.8	15.6	17.2	26.30	26.90	27.80	31.5	37.9	39.50	35
4	Specific conductance (µmho/cm)	225	610	430	320.50	250.6	230.30	180.50	165.8	136.3	110
B	**Organic Parameters (mg/l)**										
1	D.O.	6.7	4.81	4.25	3.50	3.40	3.20	4.20	7.10	7.90	8.2
2	BOD	2.1	8.6	8.62	24.60	25.10	53.10	14.20	12.2	3.30	1.2
3	COD	11	41.22	41.3	64.70	65.40	108.00	52.20	28.40	20.10	3.8
4	TKN	1.85	3.52	3.55	3.82	3.90	3.95	2.91	2.65	1.55	1.2
5	Oil & Grease	-	3.1	3.09	2.55	2.70	1.70	145	1.20	1.0	0.1
6	Phenolic compounds	-	0.188	0.187	0.154	0.152	0.10	0.10	0.095	0.09	-
C	**Mineral Parameters (mg/l)**										
1	Sulphide	0.05	0.099	0.098	0.098	0.098	0.097	0.096	0.094	0.092	0.
2	Sulphate	0.05	18.5	19.5	20.10	20.60	21.80	20.10	16.50	11.50	10.
3	Chloride	12.8	22.1	22.2	24.45	24.70	29.20	26.30	23.2	21.2	7.2
4	Fluoride	0.05	0.1	0.099	0.082	0.082	0.089	0.089	0.087	0.088	0.
5	Phosphate	3.0	0.75	0.72	0.81	0.850	0.91	0.82	0.69	0.5	0.1
D	**Other Inorganic Parameters (mg/l)**										
1	Nitrate	0.08	0.85	0.83	1.20	1.35	1.67	1.10	0.55	0.30	0.1
2	Ammonical nitrogen	0.03	2.5	2.45	2.01	1.75	1.54	1.25	0.90	0.41	0.2
3	TDS	95.1	172.5	166.3	185.30	185.80	187.4	155.5	105.70	84.2	90.
4	TSS	19.0	19.9	20.3	23.23	24.62	55.0	42.30	31.40	20.0	12.
5	TS	114.1	192.4	186.6	208.53	210.42	242.40	197.80	137.10	104.20	103.
E	**Bacteriological parameters (MPN/100ml)**										
1	Total Coliform	10,300	2500	3000	120,000	82000	78000	58000	50,000	46000	125
2	Faecal coliform	800	400	500	32,500	28500	31500	19500	13,300	9500	11

6.2.2 Post Monsoon

The season is moderate temperature and less rainfall with respect to the summer. Two water samples in October and one in November 2005 from each sampling station of the Tunia and Champamati river are analysed for the required parameters. Heavy rainfall has been observed in October during the time of analysis. The water samples of Champamati river before confluence of the Tunia river is also analysed for ascertaining the pollutional status of the Champamati river.

Besides, the effluents of BRPL, NEGPL, BCL, and C&W workshop and sewage water of Railway colony, New Bongaigaon Railway station and Bongaigaon town are also analysed accordingly.

The details of average water quality of physicochemical and bacteriological parameters at the various sampling stations of the Tunia and Champamati river are tabulated against the effluents and sewage water quality of the various units in the Table 6.3 for the postmonsoon period.

The brief average water quality of the Tunia and Champamati river at the various sampling stations are summarized in the Table 6.4 for the post monsoon.

Table 6.3: Water quality of the Tunia and Champamati river against the effluents and sewage water of the various units, post monsoon, 2005

S.No.	Sampling stations	Conflunce from	pH	Temp. °C	Turb NTU	DO mg/l	BOD mg/l	COD mg/l	TKN mg/l	Oil & Grease mg/l	Phe. Comps mg/l	Sulphide mg/l	Sulphate mg/l	Chloride mg/l	Fluoride mg/l	Phosphate mg/l	Nitrate mg/l	Amm. nitrogen mg/l	TDS mg/l	TSS mg/l	Total coliform MPN/100	Faecal coliform MPN/100
1	SS_0		7.23	25.43	12.50	6.83	2.44	10.40	1.80	-	-	0.056	0.056	13.10	0.057	3.20	0.10	0.03	96.50	19.20	10,430	820.00
2		BRPL	7.10	26.10	16.50	4.20	14.20	61.30	4.32	3.90	0.29	0.19	30.10	32.60	0.150	0.130	2.10	3.80	380.00	18.50	-	-
3	SS_1		7.20	25.52	14.06	4.64	9.66	42.80	3.58	3.40	0.202	0.144	19.60	23.10	0.114	0.814	0.902	2.60	176.80	20.96	2,400.00	360.00
4		NEGPL	7.15	25.60	15.90	4.10	10.20	44.10	3.46	-	-	0.13	20.10	23.9	0.12	0.51	0.61	2.30	181.10	72.10	-	-
5		BCL	7.10	25.20	15.30	4.20	9.70	43.90	3.51	-	0.115	0.14	21.30	24.1	0.13	0.91	0.94	2.90	167.40	43.80	-	-
6	SS_2		7.10	25.50	15.38	4.31	9.71	43.60	3.47	3.31	0.199	0.143	20.40	23.46	0.114	0.784	0.866	2.52	177.20	21.40	2,610.00	376.00
7		Rly. Colony	7.50	25.81	48.50	2.80	95.00	172.00	3.91	0.15	0.081	0.092	25.50	28.60	0.084	0.910	1.45	1.60	186.50	26.50	120,500.00	33,000.00
8	SS_3		7.30	25.58	24.04	3.70	26.67	67.20	3.76	2.75	0.166	0.136	20.56	25.51	0.095	0.848	1.308	2.104	187.80	34.56	120,000.00	32,300.00
9		C&W work shop & New Bon.Rly. Station	7.60	25.20	25.30	3.10	33.10	82.00	4.10	4.50	0.06	0.12	22.80	27.3	0.093	1.30	1.45	1.62	188.60	29.60	63,000.00	11,500.00
10	SS_4		7.40	25.50	24.44	3.60	27.36	68.65	3.89	2.88	0.167	0.135	21.30	25.81	0.094	0.910	1.494	1.874	187.90	35.87	82,500.00	29,500.00
11		Bongaigaon town	6.90	25.80	27.90	3.20	96.30	171.60	4.40	1.40	0.06	0.12	26.10	33.30	0.10	1.10	1.90	1.54	190.20	105.00	75,000.00	42,100.00
12	SS_5		7.22	25.58	25.24	3.52	52.24	111.65	4.10	1.80	0.10	0.142	22.10	30.86	0.097	0.944	1.78	1.64	188.20	68.75	78,000.00	3,200.00
13	SS_6		7.20	25.30	30.20	4.20	16.50	56.50	2.90	1.50	0.10	0.12	20.50	28.20	0.09	0.85	1.20	1.35	160.50	60.10	65,000.00	24,000.00
14	SS_7		7.10	25.10	35.50	7.20	10.50	32.50	2.60	1.40	0.09	0.11	15.20	24.50	0.10	0.73	0.62	0.98	110.80	35.20	52,000.00	16,000.00
15	SS_8		7.10	25.00	38.50	7.50	3.80	21.20	1.50	1.10	0.08	0.10	13.40	20.50	0.10	0.55	0.35	0.45	85.20	30.60	46,000.00	9,800.00
16		Champamati river before confluence	7.00	24.80	32.30	8.50	1.2	3.60	0.95	0.96	-	0.05	8.30	7.11	0.09	0.08	0.09	0.15	98.30	6.80	350.00	110.00
17	SS_9	Champamati river after confluence	7.05	24.50	29.50	8.40	1.20	3.80	1.20	0.06	0.04	0.08	9.50	7.30	0.10	0.10	0.15	0.25	95.00	20.50	11,000.00	950.00

Table 6. 4: Water quality of the Tunia river at vairous sampling stations in post monsoon, 2005

S.No.	Parameters	SS_0	SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_7	SS_8	SS_9
A	**Physical Parameters**										
1	pH	7.23	7.20	7.10	7.30	7.40	7.22	7.20	7.10	7.10	7.05
2	Temperature (^0C)	25.43	25.52	25.50	25.58	25.50	25.50	25.3	25.10	25.00	24.50
3	Turbidity (NTU)	12.50	14.06	15.38	24.04	24.44	25.24	30.2	35.50	38.50	29.50
4	Specific conductance (μmho/cm)	230.50	614.0	448.26	315.52	248.5	226.70	190.20	170.5	140.4	115.6
B	**Organic Parameters (mg/l)**										
1	D.O.	6.83	4.64	4.31	3.7	3.60	3.52	4.20	7.20	7.50	8.4
2	BOD	2.44	9.66	9.71	26.67	27.36	52.24	16.50	10.50	3.80	1.20
3	COD	10.40	42.80	43.6	67.20	68.65	111.65	56.50	32.50	21.20	3.80
4	TKN	1.80	3.58	3.47	3.76	3.89	4.10	2.90	2.60	1.50	1.2
5	Oil & Grease	-	3.40	3.31	2.75	2.88	1.80	1.50	1.40	1.10	0.06
6	Phenolic compounds	-	0.202	0.199	0.166	0.167	0.10	0.10	0.09	0.08	0.04
C	**Mineral Parameters (mg/l)**										
1	Sulphide	0.056	0.144	0.143	0.136	0.135	0.142	0.12	0.11	0.10	0.08
2	Sulphate	0.056	19.6	20.40	20.56	21.30	22.10	20.50	15.20	13.40	9.50
3	Chloride	13.10	23.18	23.46	25.51	25.81	30.86	28.20	24.5	20.50	7.30
4	Fluoride	0.057	0.114	0.114	0.095	0.094	0.097	0.09	0.1	0.10	0.10
5	Phosphate	3.20	0.814	0.784	0.848	0.910	0.944	0.85	0.73	0.55	0.10
D	**Other Inorganic Parameters (mg/l)**										
1	Nitrate	0.10	0.902	0.866	1.308	1.494	1.78	1.20	0.62	0.35	0.15
2	Ammonical nitrogen	0.03	2.60	2.52	2.104	1.874	1.64	1.35	0.98	0.45	0.25
3	TDS	96.5	176.80	177.20	187.80	187.90	188.20	160.50	110.80	85.20	95.00
4	TSS	19.20	20.96	21.40	34.56	35.87	68.75	60.10	35.20	30.60	20.50
5	TS	115.70	197.76	198.34	223.36	223.77	256.95	220.60	146.00	115.80	115.50
E	**Bacteriological parameters (MPN/100ml)**										
1	Total Coliform	10,430	2400	2610	120,000	82500	78000	65000	52,000	46000	11000
2	Faecal coliform	820	360	376	32,300	29500	32000	24000	16,000	9800	950

6.2.3 Winter

This season is lower temperature and less humidity. Rainfall is not observed. Two water samples in January and one in February 2006 are analyzed at each sampling stations of the Tunia and Champamati river. The water samples of the Champamati river is also analysed before confluence of the Tunia river.

The effluents of the BRPL, NEGPL, BCL, and C&W workshop and sewage water of the Railway colony, New Bongaigaon Railway station and Bongaigaon town are analysed accordingly for the required parameters.

The details of average water quality of physicochemical and bacteriological parameters at the various sampling stations of the Tunia and Champamati river are tabulated against the effluents and sewage water quality of the various units in the Table 6.5 for the winter.

The brief average water quality of the Tunia and Champamati river are also summarized at the various sampling stations in the Table 6.6 for the winter.

Table 6.5: Water quality of the Tunia and Champamati river against the effluents and sewage water of the various units, winter, 2006

S.No.	Sampling stations	Conflunce from	pH	Temp. °C	Turb NTU	DO mg/l	BOD mg/l	COD mg/l	TKN mg/l	Oil & Grease mg/l	Phe. Comps mg/l	Sulphide mg/l	Sulphate mg/l	Chloride mg/l	Fluoride mg/l	Phosphate mg/l	Nitrate mg/l	Amm. nitrogen mg/l	TDS mg/l	TSS mg/l	Total coliform MPN/100	Faecal coliform MPN/100
1	SS_0		7.12	19.90	9.98	6.58	2.42	11.08	1.84	-	-	0.062	0.058	13.54	0.058	3.54	0.104	0.042	95.72	19.06	8,460	850
2		BRPL	6.45	22.30	28.40	4.35	8.10	65.30	4.59	4.10	3.1	0.21	23.5	29.3	0.16	0.81	3.1	3.8	390.00	20.5	-	-
3	SS_1		6.94	20.40	17.24	4.36	9.78	48.70	3.524	3.54	2.28	0.163	20.32	22.26	0.127	0.858	0.944	2.21	177.38	21.36	2,500	360
4		NEGPL	8.85	20.30	16.40	5.20	16.70	81.30	3.45	-		0.15	18.3	33.9	0.125	-	0.85	2.30	184.00	79	-	-
5		BCL	7.20	19.80	16.80	4.10	4.90	51.20	3.51	-	0.20	0.21	19.4	26.3	0.10	-	0.75	2.00	142.00	43	-	-
6	SS_2		6.96	20.20	17.90	4.26	9.81	48.84	3.444	3.42	2.14	0.147	20.62	23.94	0.127	0.806	0.896	2.16	179.62	21.66	2,400	380
7		Rly. Colony	7.25	21.80	21.50	2.60	110.00	172.00	3.90	0.142	0.09	0.130	21.4	36.2	0.08	1.20	3.2	1.82	201.3	99	160,500	64,500
8	SS_3		7.18	20.52	18.16	3.56	27.78	68.32	3.574	2.86	1.94	0.142	20.88	25.68	0.116	0.944	1.34	2.034	189.20	35.36	90,400	29,340
9		C&W work shop & New Bon.Rly. Station	7.80	21.70	21.40	2.70	46.80	98.10	4.98	4.3	0.8	0.12	23.5	27.6	0.115	1.10	1.60	0.82	186.30	21.20	120,500	33,100
10	SS_4		7.28	20.38	18.04	3.48	28.68	69.44	3.80	2.87	1.84	0.144	21.38	25.78	0.116	1.0	1.52	1.866	188.66	36.26	85,040	29,500
11		Bongaigaon town	7.14	19.50	21.30	3.10	96.20	171.00	4.90	1.90	0.80	0.139	25.30	39.3	0.11	1.90	2.10	1.20	190.40	105	75,600	42,500
12	SS_5		7.14	20.20	18.62	3.41	53.66	107.80	4.56	1.92	1.24	0.148	22.18	31.32	0.112	1.36	1.85	1.59	188.78	67.88	72,200	28,540
13	SS_6		7.10	19.68	28.34	4.06	17.32	58.78	3.06	1.78	0.11	0.132	20.14	29.74	0.120	0.968	1.42	1.392	165.70	61.82	62,040	23,200
14	SS_7		7.10	19.48	28.20	6.90	11.24	33.32	2.70	1.52	0.10	0.123	14.54	26.26	0.098	0.826	0.836	1.20	115.78	36.62	51,080	14,540
15	SS_8		7.03	19.18	28.06	7.38	4.06	22.38	1.50	1.20	0.09	0.113	12.84	31.32	0.093	0.598	0.474	0.678	86.64	30.04	45,540	9,140
16		river before confluence	7.01	19.00	28.00	8.34	1.0	4.20	1.1	0.05	-	0.1	6.25	7.34	0.09	0.04	0.07	0.08	91.00	4.60	220	80
17	SS_9	river after confluence	7.02	19.14	28.10	8.37	1.24	4.06	1.28	0.063	0.053	0.104	9.24	10.14	0.09	0.266	0.220	0.274	91.78	22.26	10,140	968

Table 6.6: Water quality of the Tunia river at vairous sampling stations in winter, 2006

S.No.	Parameters	SS_0	SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_7	SS_8	S
A	**Physical Parameters**										
1	pH	7.12	6.94	6.96	7.18	7.28	7.14	7.10	7.10	7.03	7
2	Temperature (^0C)	19.90	20.4	20.20	20.52	20.38	20.20	19.68	19.48	19.18	1
3	Turbidity (NTU)	9.98	17.24	17.9	18.16	18.04	18.62	28.34	28.20	28.06	2
4	Specific conductance (μmho/cm)	231.2	637	474	322	256.60	238	190.14	172.06	143.04	11
B	**Organic Parameters (mg/l)**										
1	D.O.	6.58	4.36	4.26	3.56	3.48	3.41	4.06	6.90	7.38	8.
2	BOD	2.42	9.78	9.81	27.78	28.68	53.66	17.32	11.24	4.06	1.
3	COD	11.08	48.70	48.84	68.32	69.44	107.80	58.78	33.32	22.38	4.
4	TKN	1.84	3.524	3.444	3.574	3.80	4.56	3.06	2.70	1.50	1.
5	Oil & Grease	-	3.54	3.42	2.86	2.87	1.92	1.78	1.52	1.20	0.
6	Phenolic compounds	-	2.28	2.14	1.94	1.84	1.24	0.11	0.10	0.09	0.
C	**Mineral Parameters (mg/l)**										
1	Sulphide	0.062	0.163	0.147	0.142	0.144	0.148	0.132	0.123	0.113	0.
2	Sulphate	0.058	20.32	20.62	20.88	21.38	22.18	20.14	14.54	12.84	9.
3	Chloride	13.54	22.66	23.84	25.68	25.78	31.32	29.74	26.26	21.32	10
4	Fluoride	0.058	0.127	0.127	0.116	0.116	0.112	0.120	0.098	0.093	0.
5	Phosphate	3.54	0.858	0.806	0.944	1.0	1.36	0.968	0.826	0.598	0.
D	**Other Inorganic Parameters (mg/l)**										
1	Nitrate	0.104	0.944	0.896	1.34	1.522	1.85	1.42	0.836	0.474	0.
2	Ammonical nitrogen	0.042	2.21	2.16	2.034	1.866	1.59	1.392	1.12	0.678	0.
3	TDS	95.72	177.38	179.62	189.20	188.66	188.78	165.70	115.78	86.64	91.
4	TSS	19.06	21.36	21.66	35.36	36.26	67.88	61.82	36.62	30.04	22.
5	TS	114.78	198.74	201.28	224.56	224.92	256.66	227.52	152.4	116.68	114
E	**Bacteriological parameters (MPN/100ml)**										
1	Total Coliform	8,460	2100	2400	90,400	85040	72200	62040	51,080	45540	101
2	Faecal coliform	850	360	380	29,340	29500	28540	23200	14,540	9140	9

6.2.4 Premonsoon

Temperature and humidity is gradually increasing trend in the pre-monsoon period in the study area. The river is under lean flow due to scanty rainfall and hence the water quality is deteriorated. Therefore, aquatic plants are vigorously grown in the river.

One water samples in April 2006 are analyzed at each sampling stations of the Tunia and Champamati river. The water samples of the Champamati river is also analyzed before confluence of the Tunia river.

The effluents of the BRPL, NEGPL, BCL and C&W workshop and sewage water of the Railway colony, New Bongaigaon Railway station and Bongaigaon town are analyzed accordingly for the required parameters.

The details of average water quality of physicochemical and bacteriological parameters at the various sampling stations of the Tunia and Champamati river are tabulated against the effluents and sewage water quality of the various units in the Table 6.7 for the premonsoon.

The brief average water quality of the Tunia and Champamati river are summarized at the various sapling stations in the Table 6.8 for the pre-monsoon.

Table 6.7: Water quality of the Tunia and Champamati river against the effluents and sewage water of the various units, premonsoon, 2006

S.No.	Sampling stations	Confluence from	pH	Temp. °C	Turb NTU	DO mg/l	BOD mg/l	COD mg/l	TKN mg/l	Oil & Grease mg/l	Phe. Comps mg/l	Sulphide mg/l	Sulphate mg/l	Chloride mg/l	Fluoride mg/l	Phosphate mg/l	Nitrate mg/l	Amm. nitrogen mg/l	TDS mg/l	TSS mg/l	Total coliform MPN/100	Faecal coliform MPN/100
1	SS_0		7.15	26.50	10.50	5.80	3.10	12.1	2.10	-	-	0.08	0.07	14.50	0.06	3.90	0.15	0.05	101.5	20.1	10,500	1,150
2		BRPL	6.50	28.30	26.0	4.01	21.50	64.5	4.51	4.35	3.30	0.35	38.8	28.9	0.19	0.10	3.10	4.10	415	22.3	-	-
3	SS_1		6.75	27.20	18.8	4.20	11.20	50.2	3.80	3.65	2.45	0.20	21.20	23.20	0.13	1.10	1.10	2.50	180.60	22.4	2,600	380
4		NEGPL	8.1	28.30	19.2	4.0	11.3	53.10	3.63	3.61	2.44	0.17	21.9	23.50	0.14	0.09	0.098	2.10	181.3	24	-	-
5		BCL	7.3	27.00	19.10	3.90	11.40	52.30	3.61	3.55	2.38	0.173	21.8	23.60	0.13	0.093	0.096	2.15	145	43.1	-	-
6	SS_2		6.86	27.10	19.20	4.10	11.50	51.80	3.67	3.58	2.31	0.180	21.90	23.80	0.139	1.0	1.0	2.30	182.30	22.60	2,900	420
7		Rly. Colony	7.40	26.50	22.30	3.00	98	172	3.80	2.60	1.85	0.165	24.50	28.70	0.110	0.095	0.1	2.0	188.4	48.6	165,000	65,000
8	SS_3		7.15	26.90	20.1	3.20	30.30	71.80	3.70	3.10	1.95	0.17	22.10	26.58	0.125	0.98	0.151	2.10	193.20	37.80	95,800	31,200
9		C&W work shop & New Bon.Rly. Station	7.40	29.80	18.30	2.85	46.4	92.00	3.95	2.30	1.65	0.193	24.80	28.60	0.131	1.40	0.171	1.650	198.1	41.2	82,500	32,200
10	SS_4		7.25	27.30	19.90	3.0	32.20	73.30	3.85	2.95	1.87	0.18	22.70	26.90	0.129	1.10	1.67	1.95	192.50	38.90	90,300	31,500
11		Bongaigaon town	7.10	27.40	21.30	2.80	96.00	171.00	4.40	1.90	1.25	0.155	24.80	18.70	0.110	1.65	2.30	1.55	191.00	105	80,000	29,500
12	SS_5		7.15	27.30	20.30	2.95	55.50	110.5	3.950	2.51	1.45	1.65	23.10	23.50	0.121	1.45	1.96	1.70	192.90	68.90	85,000	30,200
13	SS_6		7.20	27.00	20.80	3.80	21.00	61.20	3.62	2.30	0.13	0.145	21.20	31.60	0.12	1.20	1.55	1.41	175.6	62.3	65,000	26,000
14	SS_7		7.15	26.80	20.80	6.30	16.00	35.30	3.20	1.90	0.11	0.136	16.30	28.50	0.099	1.10	1.20	1.0	135.8	38.50	54,000	16,500
15	SS_8		7.10	26.30	21.1	7.0	7.50	24.20	1.80	1.65	0.10	0.123	13.50	23.70	0.096	1.0	0.80	0.55	96.30	32.40	46,800	10,200
16		Champamati river before confluence	7.00	25.80	21.8	8.25	4.50	8.10	0.45	0.04	-	0.05	6.50	8.90	0.081	0.30	0.30	0.20	94.00	11.50	360	120
17	SS_9	Champamati river after confluence	7.05	26.10	21.30	8.20	3.10	5.10	1.50	0.12	0.09	0.11	10.50	12.80	0.091	0.50	0.60	0.35	98.80	27.80	11,500	1,060

Table 6.8: Water quality of the Tunia river at vairous sampling stations in premonsoon, 2006

S.No.	Parameters	SS_0	SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_7	SS_8	SS_9
A	**Physical Parameters**										
1	pH	7.15	6.75	6.86	7.15	7.25	7.15	7.20	7.15	7.10	7.05
2	Temperature (^0C)	26.50	27.20	27.1	26.90	27.30	27.30	27.0	26.80	26.30	26.10
3	Turbidity (NTU)	10.5	18.8	19.20	20.1	19.90	20.30	20.8	20.80	21.10	21.30
4	Specific conductance (µmho/cm)	235	650	500	380	310	270	220.00	190	155	125
B	**Organic Parameters (mg/l)**										
1	D.O.	5.80	4.2	4.1	3.20	3.0	2.95	3.8	6.30	7.0	8.2
2	BOD	3.10	11.20	11.50	30.30	32.20	55.50	21.0	16.0	7.5	3.10
3	COD	12.1	50.20	51.8	71.8	73.30	110.50	61.2	35.30	24.20	5.10
4	TKN	2.1	3.80	3.67	3.70	3.85	3.950	3.62	3.20	1.8	1.50
5	Oil & Grease	-	3.65	3.58	3.10	2.95	2.51	2.30	1.90	1.65	0.12
6	Phenolic compounds		2.45	2.31	1.95	1.87	1.45	0.13	0.11	0.10	0.09
C	**Mineral Parameters (mg/l)**										
1	Sulphide	0.08	0.20	0.180	0.17	0.18	0.165	0.145	0.136	0.123	0.11
2	Sulphate	0.07	21.20	21.9	22.10	22.70	23.10	21.20	16.30	13.50	10.5
3	Chloride	14.50	23.20	23.80	26.56	26.90	33.50	31.60	28.50	23.70	12.8
4	Fluoride	0.06	0.13	0.139	0.125	0.129	0.121	0.120	0.099	0.096	0.091
5	Phosphate	3.90	1.10	1.0	0.98	1.10	1.45	1.20	1.10	1.0	0.500
D	**Other Inorganic Parameters (mg/l)**										
1	Nitrate	0.15	1.10	1.0	1.51	1.67	1.96	1.55	1.20	0.80	0.600
2	Ammonical nitrogen	0.05	2.50	2.30	2.10	1.95	1.70	1.41	1.00	0.55	0.35
3	TDS	101.5	180.6	182.3	193.2	192.5	192.90	175.6	135.8	96.3	98.8
4	TSS	20.1	22.4	22.60	37.80	38.90	68.90	62.3	38.5	32.4	24.8
5	TS	121.60	203	204.90	231	231.40	261.80	237.90	174.30	128.70	123.6
E	**Bacteriological parameters (MPN/100ml)**										
1	Total Coliform	10,500	2600	2900	95,800	90300	85000	65000	54,000	46800	11500
2	Faecal coliform	1150	380	420	31,200	31500	30200	26000	16,500	10200	1060

6.2.5 Physicochemical Parameters

The physicochemical parameters are most important for ascertaining the water quality of a river system. The parameters such as physical, organic, mineral and other inorganic parameters are analysed regarding to the study of the Tunia river.

6.2.5.1 Physical parameters

The physical parameters of the Tunia river are hydrogen ion concentration (pH), temperature, turbidity and specific conductance. These are measured during the analysis and describes in below:

6.2.5.1.1 <u>Hydrogen ion concentration (pH)</u>

The pH is an important parameter in the Tunia river. It is fluctuated by receiving of effluents from the various industrial units such as BRPL, NEGPL BRFM, BCL, C&W workshop etc. and domestic waste water from Railway colony and New Bongaigaon Railway station along with the Bongaigaon town area. The temporal and spatial variation of the pH is given in the Figure 6.1:

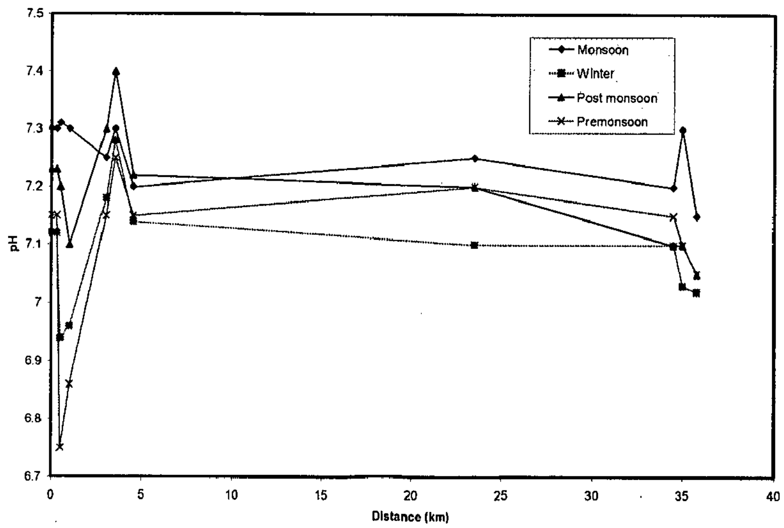

FIG. 6.1 : Temporal and spatial variation of pH

The fluctuation of pH ranges from 6.75 to 7.4 in the whole stretch of the river. The variation is under tolerable for swimming, outdoor bathing and other aesthetics purposes. The CPCB has also specified the pH ranges from 6.5 to 8.5 for bathing and other aesthetic purposes. The pH value is less than 4.5 and more than 9 is hazardous to fish and other aquatic lifes. Therefore, the pH is normal for use of river water for any purposes.

6.2.5.1.2 Temperature

The temperature are recorded at site at the time of sampling. The temperature is gradually fluctuated from sampling station SS, to sampling station SS_5 due to receiving of effluents and domestic sewage water from the various sources. The temporal and spatial variation of temperature is given in the following Figure 6.2.

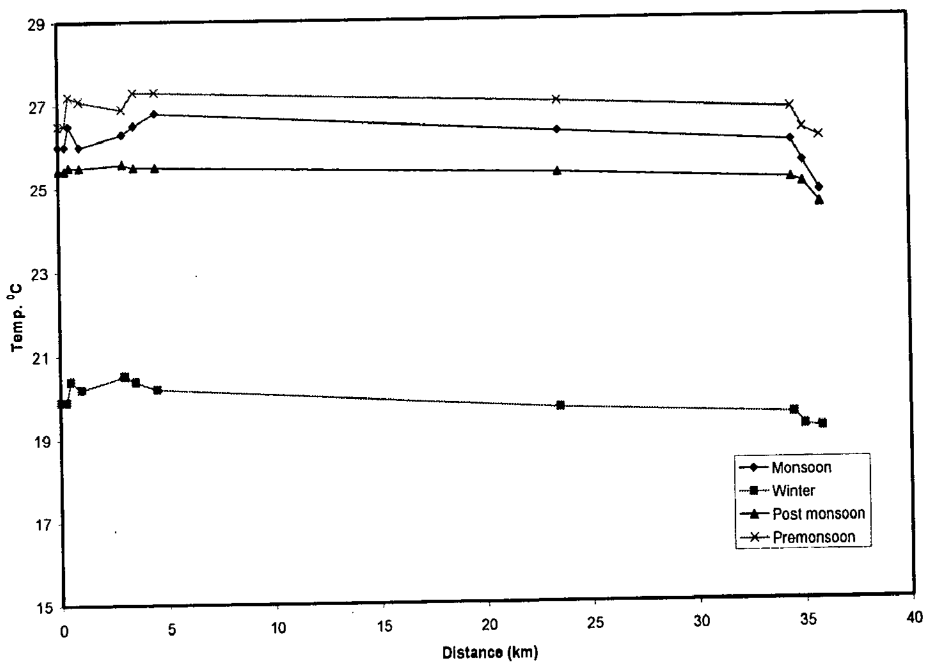

FIG. 6.2 : Temporal and spatial variation of temperature

The temperature fluctuation in the Tunia river ranges from 19.18^{0}C to 27.3^{0}C in the study period. Fluctuation of upward trend has been occurred due to receiving of effluents and sewage from the various sources. The trend of temperature change is gradually decreasing from the sampling station SS_5 to sampling station SS_9, in order to self purification and natural process of the Tunia river environment. Variation of temperature range is normal in respect of natural ambient temperature in the Assam $9^0 - 37^0$ C.

Temperature is one of the most important parameters for the aquatic environment because almost all the physical, chemical and biological properties are governed by it. The area provides almost an ideal range of solar temperature which attributes a great self purification strength in the water environment of the Tunia river.

6.2.5.1.3 Turbidity

Turbid water interferes with recreational use and aesthetic enjoyment of water. Less turbid waters are more desirable for swimming, boating and other purposes. The temporal and spatial variation of turbidity in the Tunia river is given in Figure 6.3:

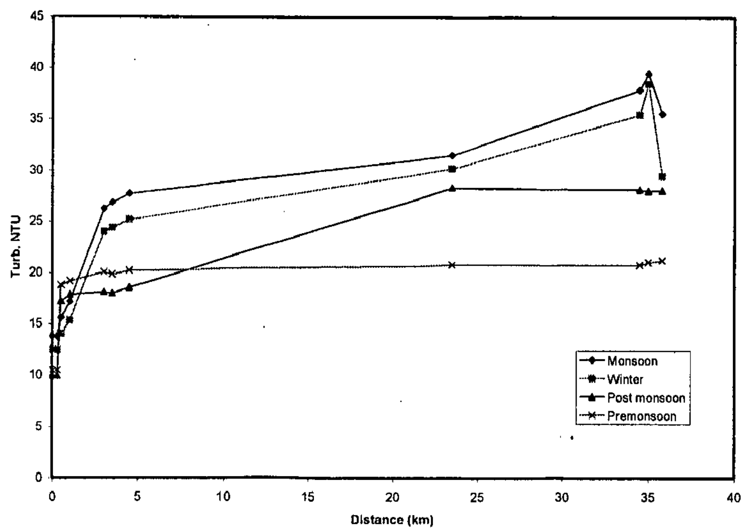

FIG. 6.3 : Temporal and spatial variation of turbidity

The fluctuation of turbidity range is observed from 10.50 to 39.50 NTU in the Tunia river. Variation of the turbidity is increasing trends upto the sampling station SS_8 and after that show decreasing trend. Turbidity is increasing in the downstream because of swimming, animal bathing, agricultural activities and erosion of the bank of the river. Similarly, turbidity is also increased due to receiving of effluents, run-off and sewage from the various sources in the upstream of the Tunia river.

Turbidity decreases light penetration and hinder to production of phytoplankton which consequently lead to decrease in photosynthetic activity and depletion of oxygen content in the water. Low turbidity means greater penetration of the light and resulting in better photosynthetic in river and leading to better water quality. The guide value set for drinking water by the WHO is 5 NTU. The CPCB does not specified any limit for primary contact of sports as far as turbidity is concerned. Therefore, the water of the Tunia river is not suitable for recreational purposes in respect of the turbidity concern.

6.2.5.1.4 Specific conductance

The specific conductance is an indirect measure of total dissolved solids in water. The temporal and spatial variation of specific conductance is shown in the following Figure 6.4:

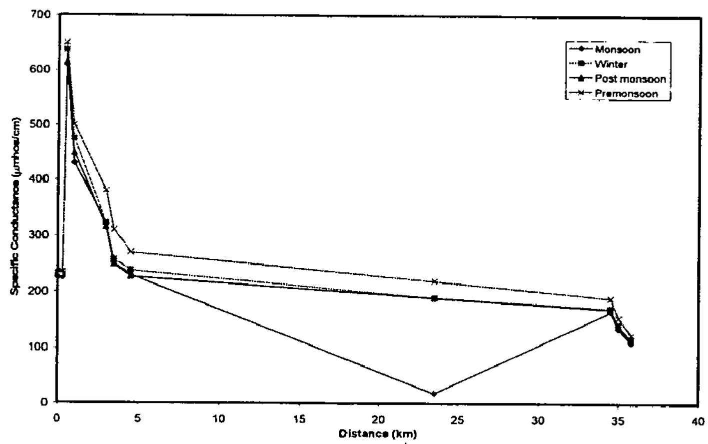

FIG. 6.4 : Temporal and spatial variation and specific conductance

The specific conductance at source is normal and no much variation. After receiving of effluent from the BRPL, the specific conductance is highly increased on average by above 2.70 times of the source value. This is cause of using poly electrolyte by the BRPL in the effluent treatment plant. The variation is a downward trend to the downstream of the river.

6.2.5.2 Organic parameters

The organic parameters are most important in regard to the river pollution. In respect of the Tunia river, the parameters are DO, BOD, COD, TKN, Oil and Grease and Phenolic components. These are described as:

6.2.5.2.1 Dissolved oxygen

The dissolved oxygen (DO) content shows the health and ability of the stream to purify itself through the biochemical process. The variation of the DO has been occurred gradually due to receiving of effluents and sewage water from the various sources. The temporal and spatial variation of DO is given in the Figure 6.5:

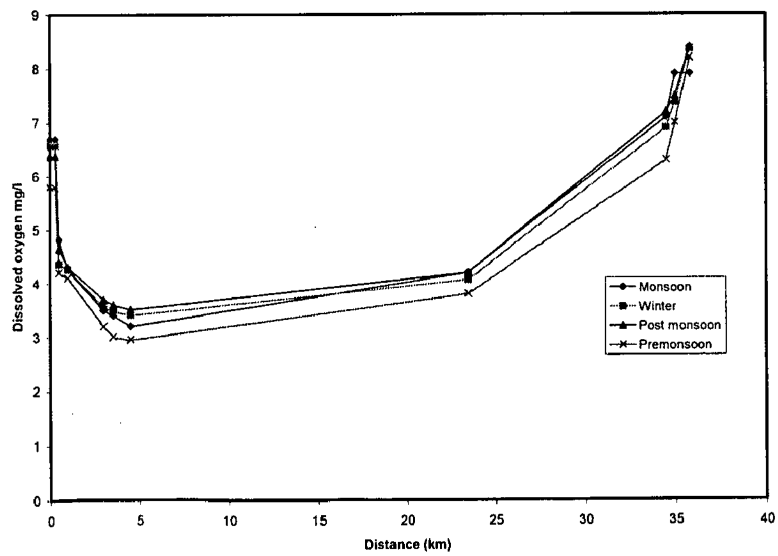

FIG. 6.5 : Temporal and spatial variation of DO

The dissolved oxygen is almost normal at the source of the Tunia river but gradually decreasing from the sampling station SS_1 to SS_5 in order to receiving of effluents and domestic sewage water from the various sources. The depletion of DO is also further depleted by the process of eutrophication in the river. This problem is vigorously occurred between the sampling station SS_1 and SS_5 of the river stretch. The DO in the sampling station from SS_1 to SS_6 is less than the required 6 mg/l as prescribed by the CPCB.

The fluctuation range is from 2.95 to 8.40 mg/l which is a serious cause of depleting fish and other aquatic fauna in the water system of the Tunia river. The DO value at the sampling station SS_5 is a critical limit for sustaining the river eco-system. Dissolved oxygen content is to be further depleted from the critical limit, fish and other high aquatic fauna are totally disappeared and the river shifts towards anaerobic environment. High depletion of oxygen content produces four odour due to the anaerobic decomposition of organic wastes leading to the formation of hydrogen sulphide.

The dissolved oxygen content has been gradually increased from the sampling station SS_6 to SS_9 due to self purification process of the river and consequently reappear the fish and other higher aquatic fauna in the downstream of the river.

6.2.5.2.2 Biochemical oxygen demand (BOD)

BOD represents the intensity of biodegradable organic matter remaining in the stream at any time and BOD test show the amount of molecular oxygen required by bacteria to reduce the carbonaceous materials. The temporal and spatial variation of BOD is shown in the Figure 6.6:

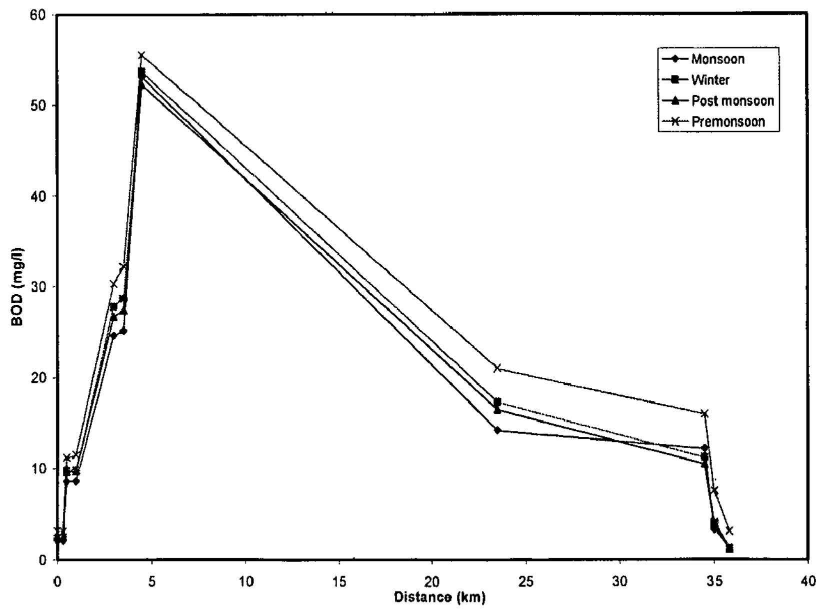

FIG. 6.6 : Temporal and spatial variation of BOD

The BOD value is more or less normal at the source of the Tunia river but constantly increases from the station SS_1 to SS_5 in order to receiving of effluents and domestic waste water from the various sources. BOD is also further increased by direct discharging of human faces to the river water through the katcha latrine.

The BOD value of the Tunia river have a decreasing trend from the sampling station SS_5 to SS_9 due to self purification process of the river. The high fluctuation range from 2.10 to 55.50 mg/l is a serious factor for deteriorating the water quality and it indicate the river is facing under organic pollution. Due to high BOD load, it influences eutrophication in the river system and depleting the dissolved oxygen ultimately which aquatic fauna are unable to sustain in the river environment.

6.2.5.2.3 Chemical oxygen demand (COD)

The COD test shows the oxygen equivalent of the organic matter that can be oxidized by using strong oxidizing agent. The temporal and spatial variation of COD is shown in the following Figure 6.7:

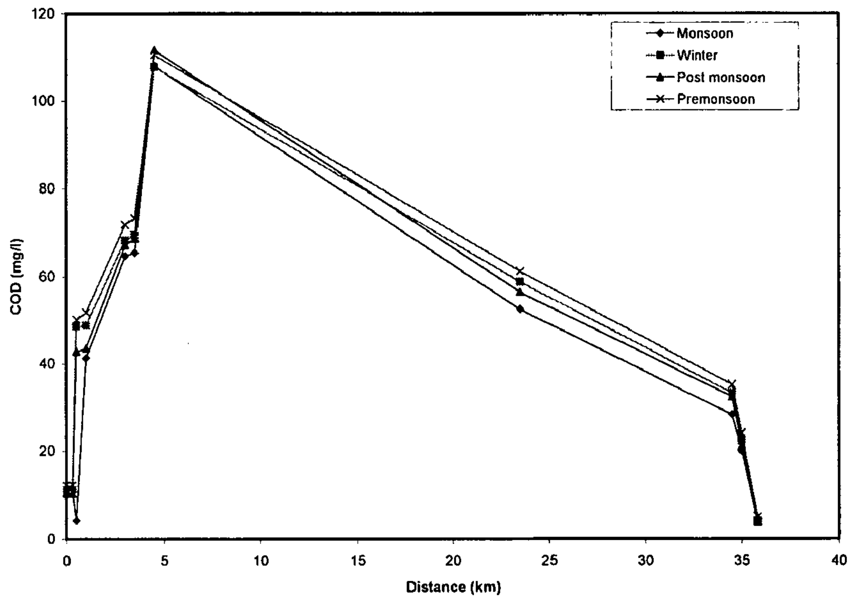

FIG. 6.7 : Temporal and spatial variation of COD

The COD value is more or less normal at the sources of the Tunia river but vigorously increases from the sampling station SS_1 and SS_5 in order to receiving of effluents and domestic sewage water from the various sources. The main contributor of COD is the BRPL unit which discharges such type of non-biodegradable organic matter into the river water.

There is a decreasing trend of COD variation from the sampling station SS_5 to SS_9 due to natural purifying system of the river.

6.2.5.2.4 Total Kjeldahal nitrogen (TKN)

The total Kjeldahal nitrogen is known as total nitrogen. The total nitrogen in water is taken to mean the sum of total of the concentrations of ammonia, nitrite, nitrate and organic nitrogen. The temporal and spatial variation of TKN is shown in the Figure 6.8:

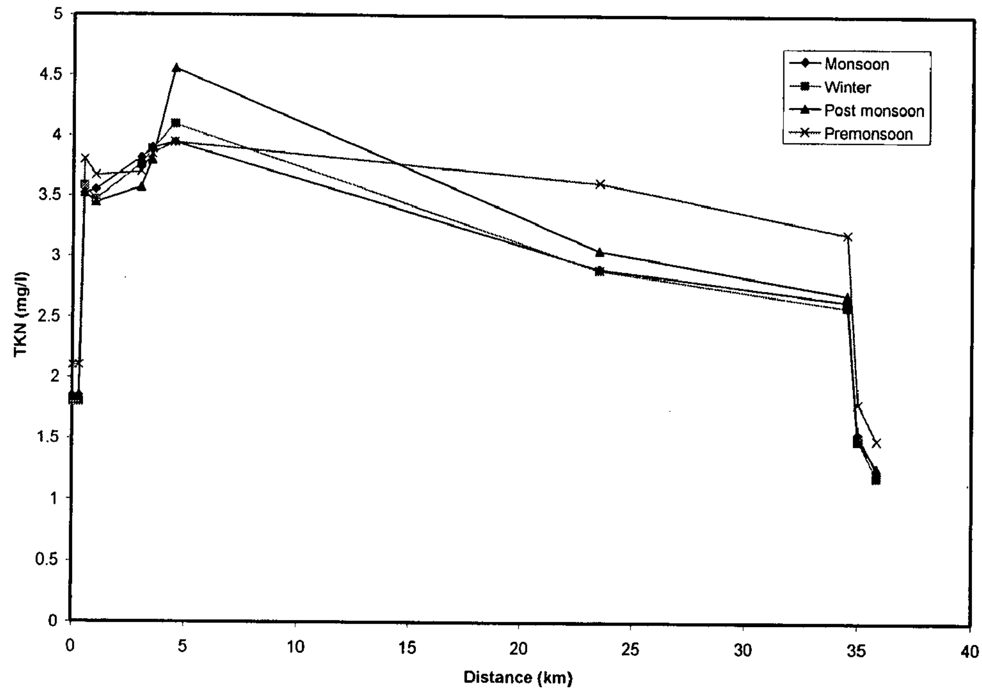

FIG. 6.8 : Temporal and spatial variation of TKN

The fluctuation range of the TKN is from 1.20 to 4.56 mg/l in the water of the Tunia river. There is an upward trend of fluctuation from the sampling station SS_1 to SS_5 in order to receiving of effluent and sewage water from the various sources and downward trend is also observed from the sampling station SS_5 to Ss_9 due to self purification and natural activity of the river. In polluted waters most of the nitrogen is the form of organic nitrogen and ammonia. At the time of progress, the organic nitrogen is gradually converted to ammonia nitrogen and later on to nitrite and nitrate by nitrify bacteria with aerobic condition.

6.2.5.2.5 Oil and grease

Oil and grease is the most important pollutant in the Tunia river which is discharged to the river by BRPL through their effluent. Therefore, it affects the flora and fauna in the river. The temporal and spatial variation of the oil and grease is shown in the Figure 6.9:

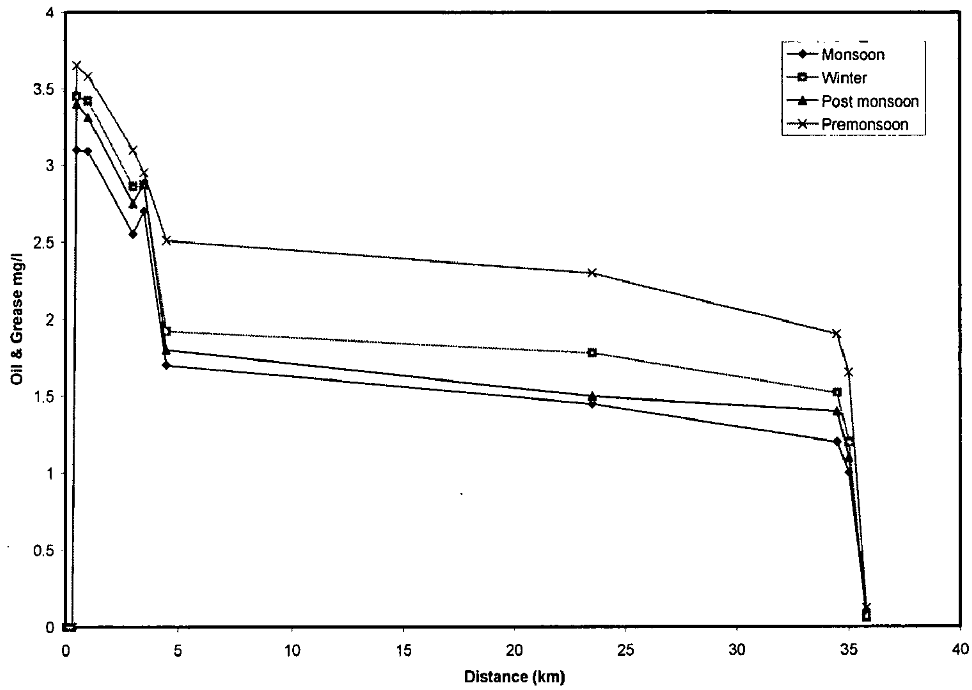

FIG. : 6.9 : Temporal and spatial variation and oil and grease

The oil and grease content is a downward trend from the upstream to the downstream of the river. The fluctuation range is from 0.1 to 3.65 mg/l in the river water and consequently, affect the aquatic lifes. The BRPL releases 27.45 kg/day of oil and greases into the Tunia river and this is the only unit which discharge oil and grease pollutant to the river but it discharge under the permissible limit of 10 mg/l as prescribed by the CPCB. Considering the affects on aquatic lifes, it indicate that the pollution carrying bearable capacity of the Tunia river is less with compare to the other rivers.

Oil and grease forms a film on the surface of water and consequently, it obstructs the fish to take oxygen from the air through the gills. Oil and grease also affects the gills badly ultimately which damages their oxygen receiving capacity. Similarly, oil and grease also affect the aquatic plants which is observed in and around the sampling station of SS_1. Higher aquatic plants are not grown except for the algae at this station.

6.2.5.2.6 Phenolic Compounds

The phenolic compounds is the most important pollutant in the Tunia river which is discharged by the BRPL through their effluent. The affect is more in winter and premonsoon season. The temporal and spatial variation of phenolic compound is shown in the following figure 6.10:

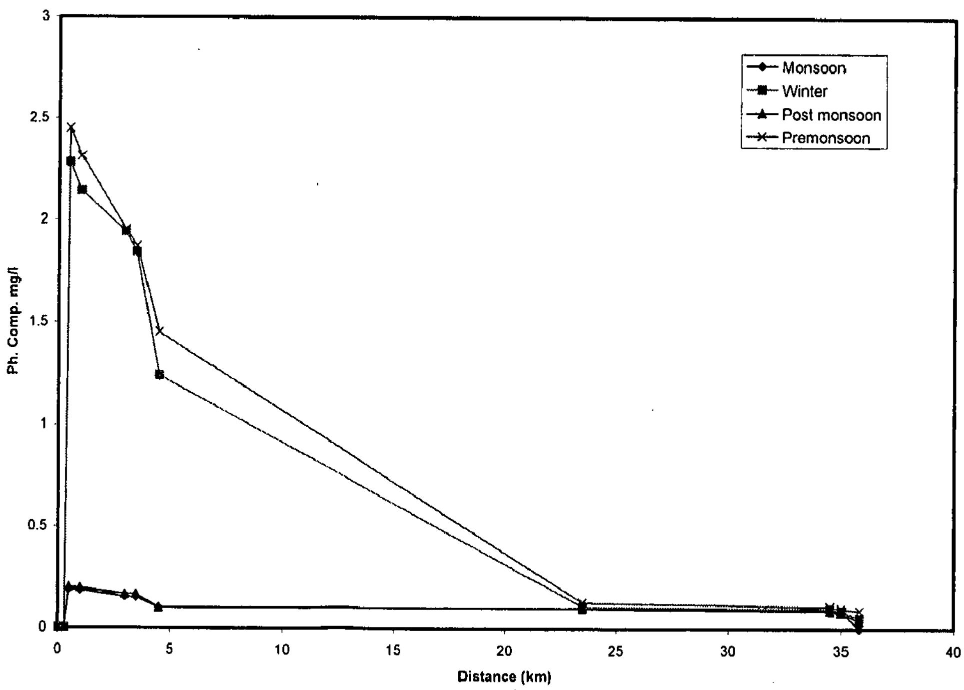

FIG. : 6.10 : Temporal and spatial variation of phenolic compounds

The fluctuation of the phenolic compounds has shown the downward trend from the sampling station SS_1 to SS_9. The BRPL discharges about 1.621 kg/day of phenolic compounds into the Tunia river water environment through their effluent. Similarly, the BCL also discharges about 12 gm of phenolic compounds in a day into the Tunia river. As a result, the flora and fauna of the river has been adversely affected in between the sampling station SS_1 and SS_2. The affect is more in winter and premonsoon season.

6.2.5.3 Mineral parameters

The mineral parameters takes important part in a river eco-system. It varies due to location and receiving of effluents and sewage from the various sources. Mineral parameters such as sulphide, sulphate, chloride, fluoride and phosphate are considered in favour of the Tunia river water system.

6.2.5.3.1 Sulphide

Sulphide is another parameter of the Tunia river. Sulphide has been contributed by the effluents from the various industrial units and sewage from the domestic activities. The temporal and spatial variation of sulphide is shown in the following Figure 6.11.

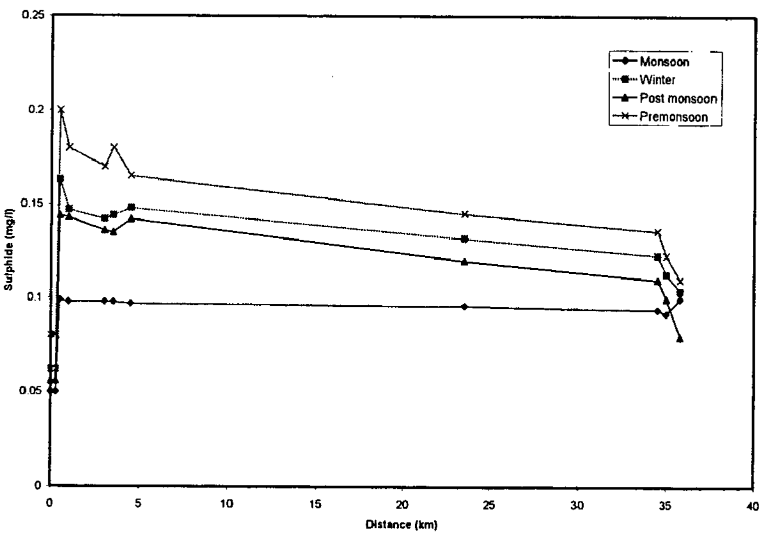

FIG. 6.11 : Temporal and spatial variation of sulphide

The fluctuation range is from 0.05 to 0.2 mg/l in the Tunia river. There is a variation of downward trend to the down stream of the river. The affect of sulphide is less in summer and more in winter and premonsoon period regarding to the flora and fauna of the river eco-system.

6.2.5.3.2 Sulphate

Sulphate is occurred in all natural water but its content is depend on its location. Sulphate concentration is increased due to receiving of sewage and effluents from the various sources. The temporal and spatial variation of sulphate is shown in the figure 6.12:

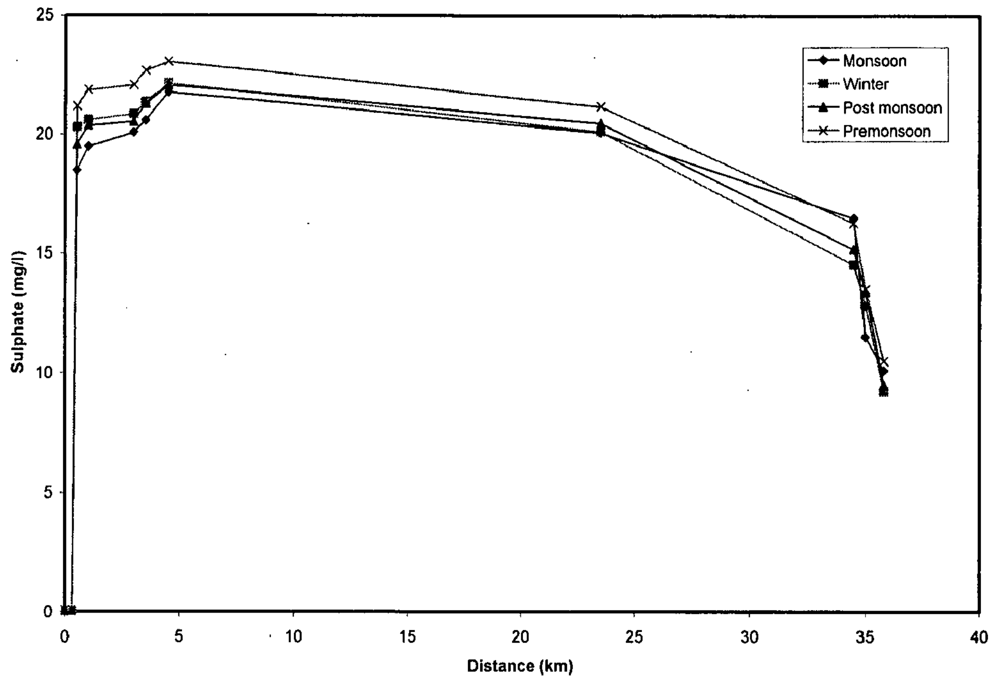

FIG. 6.12 : Temporal and spatial variation of sulphate

The fluctuation range is from 0.05 to 23.1 mg/l of sulphate in the water of the Tunia river. There is an increasing trend from the sampling station SS_1 to SS_5 and downward trend from the sampling station SS_5 to SS_9. The increasing trend is initiated by receiving of effluents and sewage and downward trend is influenced by the self purification process of the river. Sulphate produces H_2S by its reduction which is released into atmosphere. Its affects is more in winter and premonsoon period.

6.2.5.3.3 Chloride

Chloride is also another parameter in the Tunia river water. Chlorides generally occur in all natural waters in widely varying concentrations. It is harmless upto 1500 mg/l but produces a salty test at 250 – 500 mg/l. The temporal and spatial variation of chloride is shown in the figure 6.13:

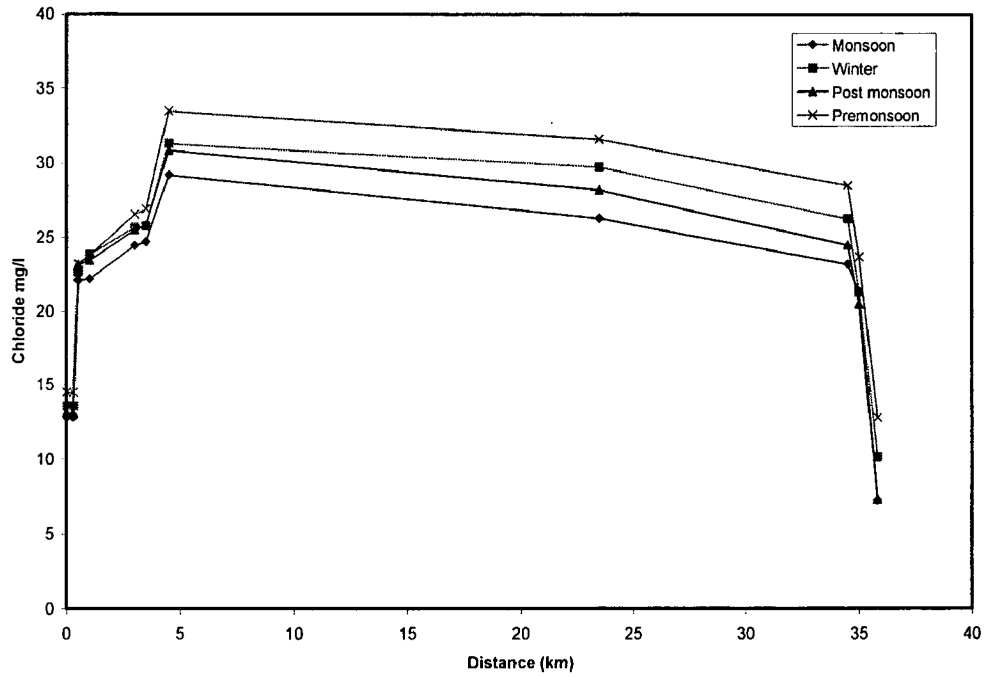

FIG. 6.13 : Temporal and spatial variation of chloride

There is an upward trend of variation from sampling station SS_1 and SS_5 and downward trend from SS_5 to Ss_9. The upward trend is influenced by receiving of effluent and sewage from the various sources. The fluctuation range is from 12.80 to 33.50 mg/l. The concentration is more in the pre-monson period. Chloride content is also increased by the human faecal matters which is discharged directly into the river by the katcha latrine at the new Bongaigaon area.

Chlorides initiates positive growth rate of Euglenophyceae which is grown between the sampling station $SS_1 - SS_5$. This algae is more resistance against the organic pollution.

6.2.5.3.4 Fluoride

Fluoride is most important parameter in a water body. Its concentration in water both at levels less than 1 mg/l or more than 1.5 mg/l are harmful for human health. But fluoride in the Tunia river is always less than the requirement. The temporal and spatial fluctuation of fluoride is shown in the Figure 6.14:

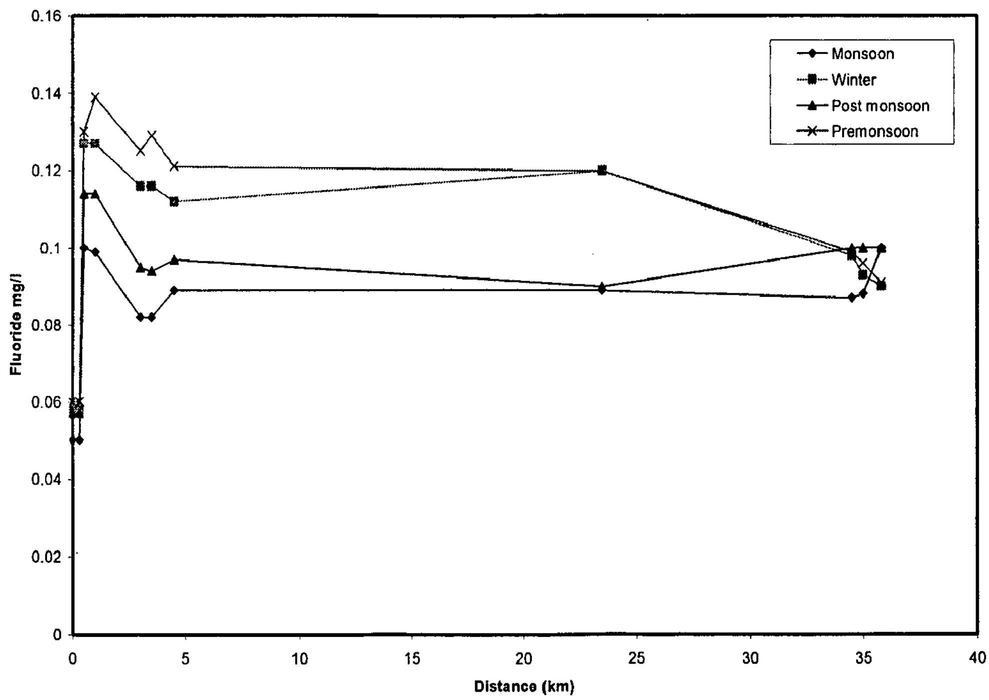

FIG. 6.14 : Temporal and spatial variation of fluoride

High concentration is occurred in the premonsoon period. There is no much fluctuation of fluoride in the Tunia river water. The water is not suitable for drinking purposes due to low fluoride content in water which initiate high incidence of dental carries.

6.2.5.3.5 Phosphate

Phosphate is most important pollutant in a water system. It induces the growth of microscopic plant life in the surface waters which produces second form of pollution. The temporal and spatial variation of phosphate is shown in the Figure 6.15:

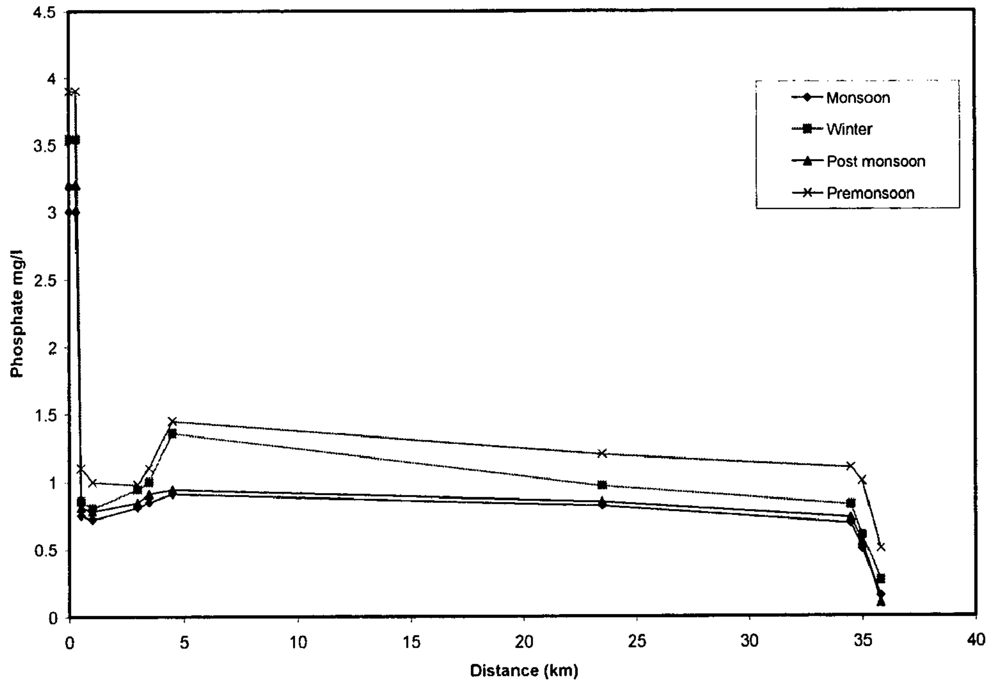

FIG. 6.15 : Temporal and spatial variation of phosphate

Phosphate content is originally high at source due to animal bathing and cow dung discharges to the grazing field which is ultimately comes to the Bher Bher beel for the source of Tunia river. After receiving of BRPL effluent, the phosphate content decreases at the sampling station SS_1.

The fluctuation range is from 0.10 to 3.90 mg/l in the study period. There is an upward fluctuation trend upto the sampling station SS_5 and downward trend from the sampling station SS_5 to SS_9. Phosphate is always taking an important part in the aquatic body. The phosphate concentration of about 0.01 mg/l initiates algal bloom which lead to the eutrophication hazards for heavy growth of Chlorophyceae and Cyanophcease. Phosphate is always above this level in the river and as a result, the whole Tunia river is facing under the eutrophication problem and depleting the dissolved oxygen in the water system. This problem is more critical during the premonsoon period. Therefore, the high level phosphate content imbalances the river ecosystem of the Tunia river.

6.2.5.4 Other inorganic parameters

These parameters also takes important part in the Tunia river. The parameters are nitrate, ammonical nitrogen, TDS, TSS and TS.

6.2.5.4.1 Nitrate

Nitrate is another pollutant in the Tunia river water. It has been observed that the nitrate nitrogen content varies from 0.04 to 5.0 mg/l in the rivers of the world. The temporal and spatial variation of nitrate is shown in the Figure 6.16:

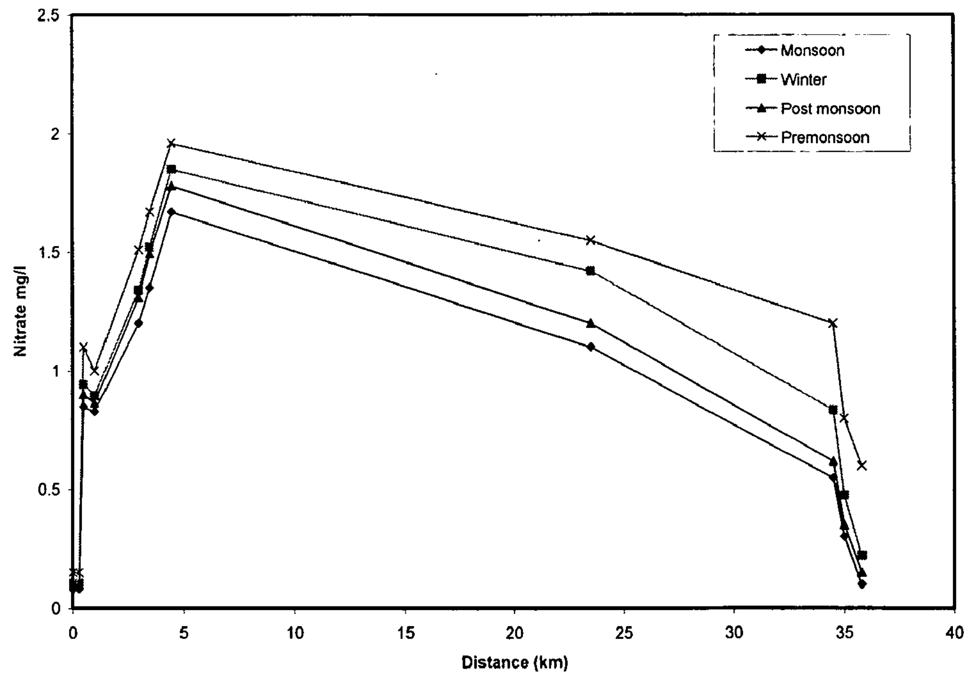

FIG. 6.16: Temporal and spatial variation of nitrate

The fluctuation range of nitrate is from 0.08 to 1.96 mg/l in the water of the Tunia river. There are upward trend from the sampling station SS_1 to SS_5 due to receiving of effluent and sewage from the various sources and downward trend from the sampling station SS_5 to SS_9 in order to the bacterial activity along with self purification process.

The presence of about 0.30 mg/l of nitrate nitrogen initiates to excessive growth of algae blooms and aquatic weeds causing undesirable colour, taste and odour, thereby degrading the aesthetic quality of surface water bodies. Basically, the river is facing the eutrophication hazards. Nitrates accelerates more growth of Chlorophyceae, Bacillariophyceae, Euglenophycease and Cyanophyceae along with higher aquatic plants in the Tunia river water system.

6.2.5.4.2 Ammonical nitrogen

High concentration of ammonical nitrogen indicate that the pollution is fresh. Most sensitive indicator of sewage pollution in a river water is sudden increase in its ammonia content and it gradually decreases by aerobic oxidation into nitrites and then into nitrates. The temporal and spatial variation of ammonical nitrogen is shown in the following figure 6.17:

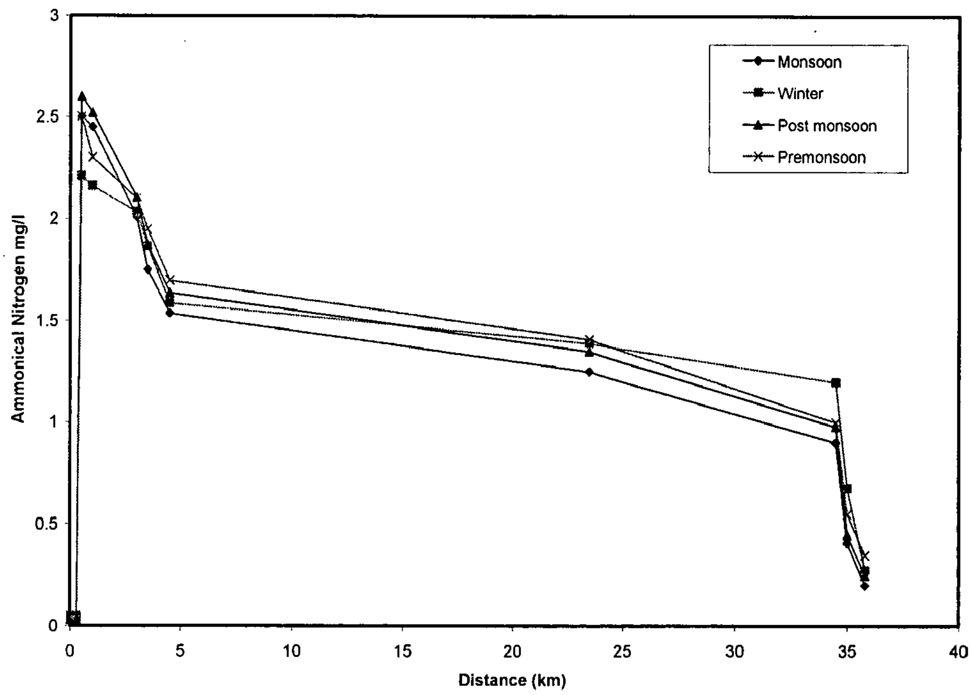

FIG. 6.17 : Temporal and spatial variation of ammonical nitrogen

The fluctuation range is 0.03 to 2.60 mg/l in the Tunia river water indicate that the organic nitrogen is gradually converted to ammonia nitrogen and consequently, the river water is to be polluted. There is a downward fluctuation trend from the sampling station SS_1 to SS_9 due to natural activity and self-purification process of the river.

6.2.5.4.3 Total dissolved solids (TDS)

Total dissolved solids are materials in the water that will pass through a filter with a 2.0 μm or smaller nominal average pore size. The total dissolved solids content of potable water usually ranges from 20 to 1000 mg/l. The total dissolved solids consist mainly of inorganic salts and small amounts of organic matter. The total dissolved solids content has been influenced by receiving of effluents and sewage in the Tunia river. The temporal and spatial variation of the total dissolved solids is shown in the following figure 6.18.

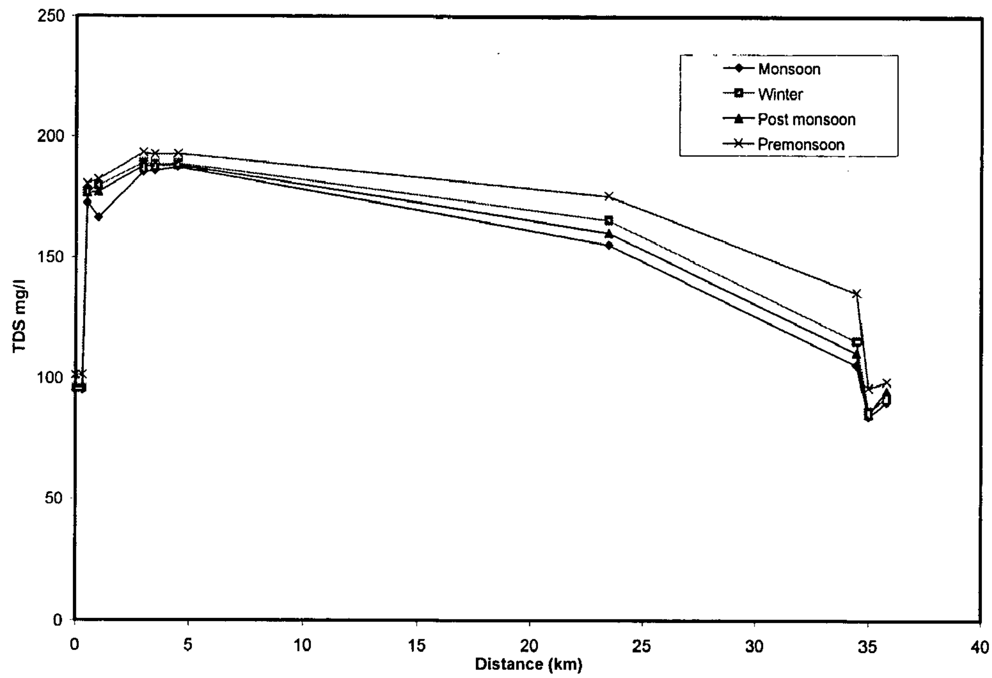

FIG. 6.18 : Temporal and spatial variation of total dissolved solids

The fluctuation range is observed from 95.1 to 193.20 mg/l in water of the Tunia river in respect of the TDS. There is an upward fluctuation trend upto the sampling station SS_5 and downward trend is observed between the sampling station SS_5 – SS_8. The Champamati river shows slightly higher TDS at the sampling station SS_9 in order to unpolluted nature of the water.

Regarding to the total dissolved solids is concerned, the water of the Tunnia river is suitable for the recreational purposes.

6.2.5.4.4 Total suspended solids (TSS)

The total suspended solids can float and form unsightly scum layers or sink and cause sediment build up. The TSS is always objectional in respect of the aesthetic purposes. The temporal and spatial variation of total suspended solids is shown in the Figure 6.19:

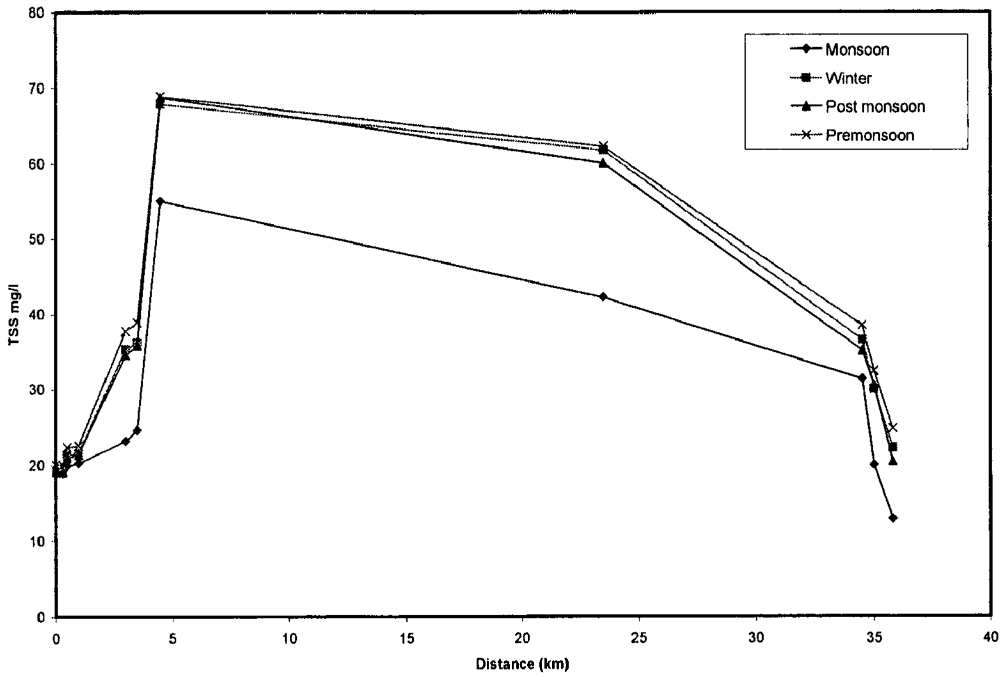

FIG. 6.19 : Temporal and spatial variation of total suspended solids

The fluctuation range of the total suspended solid is 19 – 68.90 mg/l in the water of the Tunia river. There is an upward fluctuation trend from the sampling station SS_1 to SS_5 in order to receiving of effluents and sewage from the various sources and downward trend from the sampling station SS_5 to Ss_9 is also observed due to self purification process and natural activities of the river. The suspended solids favours the creation of eutrophication hazards in the river and depleting the dissolved oxygen in the river water.

6.2.5.4.5 Total solids (TS)

The total solids in a river water consists of total dissolved solids and total suspended solids. The temporal and spatial variation of the total solids is shown in the following figure 6.20.

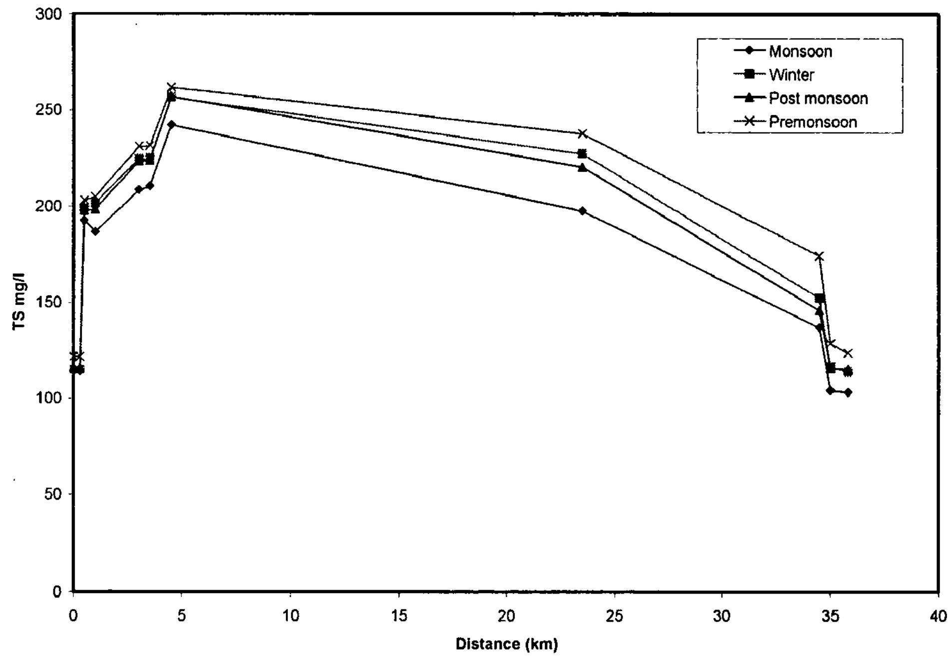

FIG. 6.20 : Temporal and spatial variation of total solids

The fluctuation range of the total solids is 114.1 – 261.80 mg/l. There is an upward trend of variation of the total solids from the sampling station SS_1 to SS_5 due to receiving of effluents and sewage from the various sources and downward trend is also observed from the sampling station SS_5 to SS_9 in order to the self purification along with the natural process of the river.

6.2.6 Bacteriological Parameters

This pollution problem is not only for the Tunia river but also in Assam. All municipal waste water are discharged into the nearby river without any treatment. Besides, the optimum temperature of 18 – 37^{0}C and favourable climate is the main cause of rapid growth of bacteriological parameters in Assam. Therefore, total coliform and faecal coliform are measured during the analysis of our study.

6.2.6.1 Total coliform

Total coliform is the most important parameters which determines the water quality of a water body. Total coliform is high in the Tunia river. The temporal and spatial variation of total coliform is shown in the Figure 6.21.

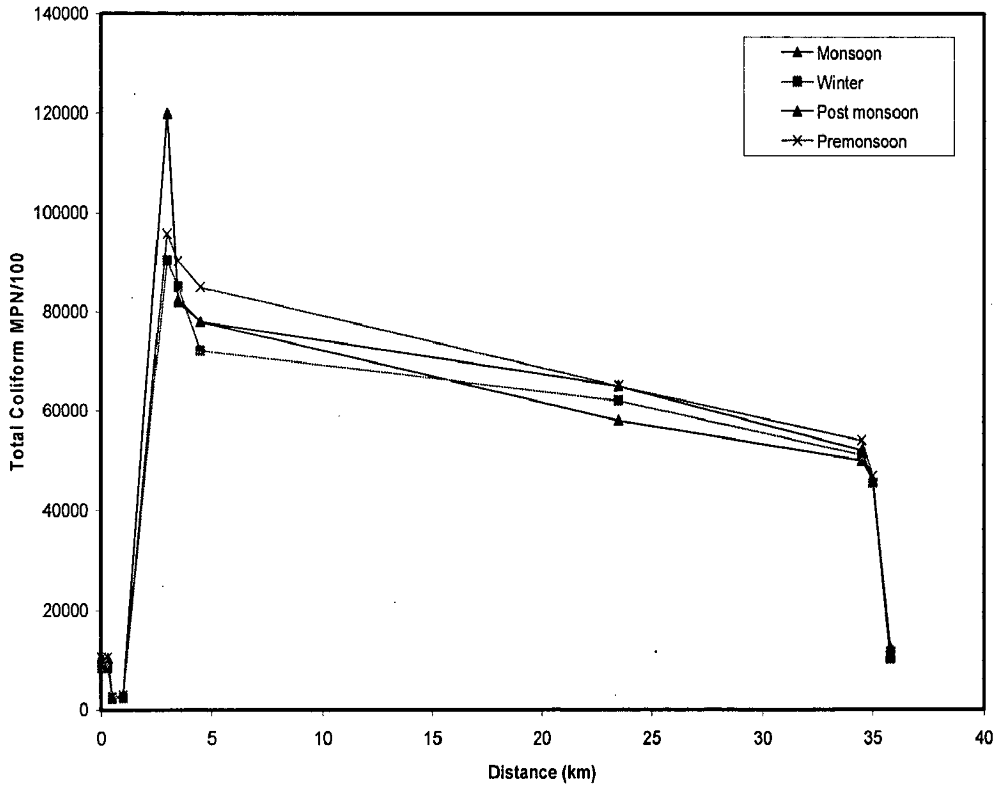

FIG. 6.21 : Temporal and spatial variation of total coliform

There is an upward trend of fluctuation from the sampling station SS_1 to SS_5 due to receiving of sewage from Railway colony, Railway station and Bongaigaon town area. The downward trend of fluctuation is occurred from the sampling station SS_5 to SS_9 in order to self purification process and natural activities of the river. Industrial effluents does not favour for the growth of the total coliform. The total coliform is gradually diminishing from the sampling station SS_0 to SS_1 due to cause of receiving of effluent from the BRPL. The heavy growth of the total coliform is happened in every river in Assam which carry domestic sewages from the nearby urban area.

The CPCB has prescribed the maximum value of the total coliform 50, 500 and 5000 MPN/100 ml for A, B and C class of water respectively. The ISI standards (IS : 229,1982) also prescribes the same limits for the surface water. The total coliform is more the above limits at all the sampling stations of the Tunia river. Consequently, this indicate that the water of the Tunia river is grossly polluted and not suitable for the recreational purposes in respect of the total coliform.

6.2.6.2 Faecal coliform

The faecal cliform is most important pollutant in the Tunia river. This coliform groups has a limitation that it has been known to multiply in water with the environmental factors tend to promote and may give an exaggerated index of pollution. The temporal and spatial variation of faecal coliform is shown in the figure 6.22.

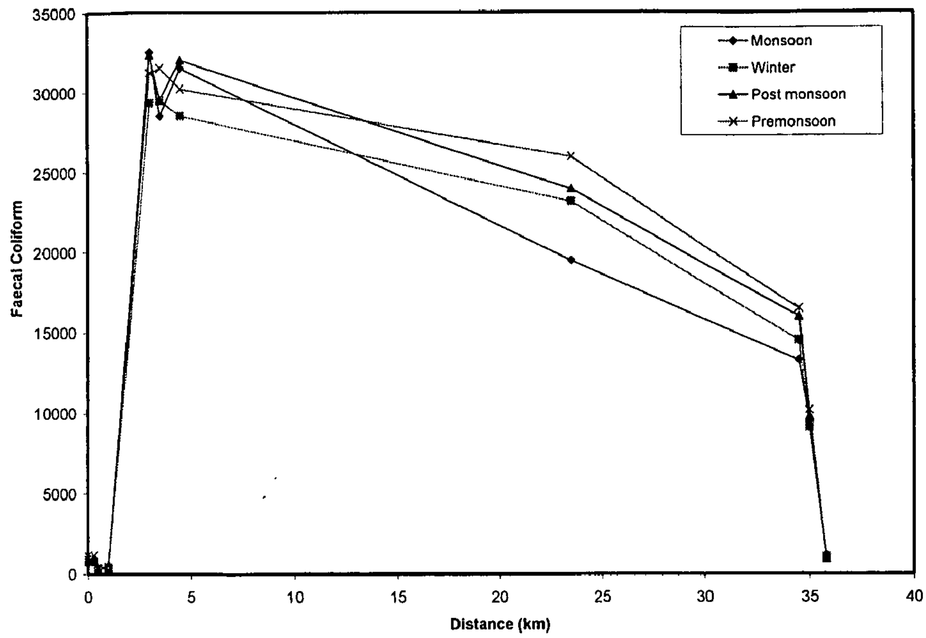

FIG. 6.22 : Temporal and spatial variation of faecal coliform

The fluctuation range of the faecal coliform is 360 – 32500 MPN/100 ml in the Tunia river. There is an upward fluctuation trend from the sampling station SS_1 to SS_5 in order to receiving of sewage from the Railway colony and Bongaigaon town area and downward trend is also observed from the sampling station SS_5 to SS_9 due to self purification and natural activity of the river. Regarding to the above, the river is grossly polluted and therefore, it is unsafe and unfit for recreational purposes.

6.3 ALGAL ANALYSIS AND IDENTIFICATION

Various algal species are occupied in the Tunia river due to its physico-chemical characteristics of the river water. There are 5 groups of 97 algal species belonging to 59 genera has been found about 35.3 km long Tunia river stretch of which 32 species belong to Bacillariophyceae, 31 species to Chlorophyceae, 26 species to Cyanophyceae, 7 species to Euglenophyceae and only one species to Rhodophyceae group.

6.3.1 Algal Species at Sampling Stations

The population of algal species are depend on the physicochemical characteristics of the river water. This has been influenced by receiving of effluents and sewages from the various sources. The presence of algal species at the various sampling stations are tabulated in the following Table 6.9 as mentioned below.

Table 6.9 : Presence of algal species at the various sampling station

Sl. No.	Algal species	Sampling Stations									
		SS_0	SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_7	SS_8	SS_9
A	**BACILLARIOPHYCEAE**										
1.	*Achananthes minutissima*	+	-	-	-	-	-	+	+	+	+
2.	*Amphora ovalis*	+	-	-	-	-	-	+	+	+	+
3.	*Asterionella species*	+	-	-	-	-	-	+	+	+	+
4.	*Caloneis species*	+	-	-	-	-	-	+	+	+	+
5.	*Cocconeis species*	+	-	-	-	-	-	+	+	+	+
6.	*Cymbella species*	-	-	-	-	-	-	+	+	+	+
7.	*Cymbella tumida*	+	-	-	-	-	-	+	+	+	+
8.	*Cyclotella meneghiniana*	-	+	+	+	+	+	+	+	+	-
9.	*Diploneis species*	-	-	-	+	+	+	+	+	-	-
10	*Eunotia species*	+	-	-	-	-	-	+	+	+	+
11.	*Fragilaria species*	-	+	+	+	+	+	+	+	+	-
12.	*Gyrosigma species*	-	-	-	-	-	+	+	+	+	-
13	*Gomphonema parvulune*	-	+	+	+	-	-	-	-	-	-
14.	*Gomphonema olivaceum*	-	+	+	+	+	+	+	-	-	-
15.	*Hantzschia amphioxys*	+	-	-	-	-	-	+	+	+	+
16.	*Melosira species*	+	-	-	-	-	-	+	+	+	+
17.	*Navicula species*	-	+	+	+	+	+	-	-	-	-
18.	*Neidium species*	+	-	-	-	-	-	-	+	+	+
19.	*Nelosira varians*	-	-	-	-	+	+	+	-	-	-
20.	*Nitreshia aciularis*	+	-	-	-	-	-	-	+	+	+
21.	*Nitzschia amphibia*	-	+	+	+	+	-	-	-	-	-
22.	*Nitzochia hungarica*	-	+	+	+	-	-	-	-	-	-
23.	*Nitzschia linearis*	-	+	+	+	+	-	-	-	-	-
24.	*Nitzschia longissima*	-	-	-	-	+	+	-	-	-	-
25.	*Nitzschia obtusa*	-	-	-	+	+	=	-	-	-	-
26.	*Nitzschia palea*	-	+	+	+	+	+	-	-	-	-
27.	*Nitzschia cuspidate*	-	-	-	-	+	+	-	-	-	-
28.	*Pinnularia species*	+	-	-	-	-	-	+	+	+	+
29.	*Rhopalodia gibba*	+	-	-	-	-	-	+	+	+	+
30.	*Synedra ulna*	-	+	+	+	+	+	+	+	+	-
31.	*Synedra ulna bicepo kuetz*	+	-	-	-	-	-	-	-	+	+
32.	*Surirella species*	-	-	-	-	-	+	+	+	=	-

Table 6.9 contd/-

Sl. No.	Algal species	Sampling Stations									
		SS_0	SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_7	SS_8	SS_9
B	**CHLOROPHYCEAE**										
1.	*Ankistrodesmus*	+	+	+	+	+	+	+	+	+	+
2.	*Ankistrodesmus convolutus*	+	-	-	+	-	-	-	-	+	+
3.	*Actinostrum hantzschill*	-	-	-	+	+	+	+	+	+	-
4.	*Chlamydomonas species*	-	+	+	+	-	-	-	-	-	-
5.	*Chlorella vulgaris*	-	+	+	+	=	-	-	-	-	-
6.	*Chlorella pyrenoidosa*	-	+	+	+	-	-	-	-	-	-
7.	*Chloroeocum humicolum*	-	-	-	+	+	+	-	-	-	-
8.	*Closterium species*	-	-	-	-	-	+	+	+	+	-
9.	*Closterium acerosum*	-	+	+	+	+	-	-	-	-	-
10.	*Cosmerium species*	-	-	-	+	+	+	+	+	+	+
11.	*Cladophora species*	-	-	-	+	+	+	-	-	-	-
12.	*Desmidium species*	-	-	-	-	+	+	+	+	+	+
13.	*Euastrum species*	-	-	-	-	-	-	-	+	+	+
14.	*Euastrum spinulosum*	-	-	-	-	-	-	-	+	+	-
15.	*Hydrodicton reticulatum*	-	-	-	-	-	-	+	+	+	-
16.	*Kirchneriella obesa*	-	-	-	-	-	-	-	+	+	-
17.	*Oedogonium species*	-	+	+	+	+	+	+	+	+	-
18.	*Pandorina species*	-	-	-	-	-	-	+	+	-	-
19.	*Pediostrum species*	-	-	-	-	-	-	+	+	-	-
20.	*Pediastrum tetras*	-	-	-	-	-	-	+	+	-	-
21.	*Scenedesmus quadricauda*	-	+	+	+	+	+	-	-	-	-
22.	*Scenedesmus bicaudatus*	-	+	+	+	+	+	-	-	-	-
23.	*Scenedesmus dimorphus*	-	+	+	+	+	+	-	-	-	-
24.	*Scenedesmus obliguus*	-	-	-	-	+	+	+	+	+	+
25.	*Stigeoclonium tenue*	-	+	+	+	+	+	-	-	-	-
26.	*Schizomeris leibleinii*	-	+	+	+	+	+	-	-	-	-
27.	*Spirogyra species*	-	-	-	-	+	+	+	+	-	-
28.	*Staurastrum species*	+	-	-	-	-	-	-	+	+	+
29.	*Staurastrum contectum*	+	-	-	-	-	-	-	-	+	+
30.	*Tetradon muticum*	-	-	-	-	+	+	-	-	-	-
31.	*Ulothrix species*	-	-	-	-	+	+	-	-	-	-

Table 6.9 contd/--

Sl. No.	Algal species	Sampling Stations									
		SS_0	SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_7	SS_8	SS_9
C	**CYANOPHYCEAE**										
1.	*Arthospira species*	+	+	+	+	+	+	+	-	-	-
2.	*Anabaena constricta*		-	-	+	+	+	+	+	+	+
3.	*Anabaena azollae*	+	-	-	-	-	-	-	+	+	+
4.	*Anabena variabilis*	-	+	+	+	+	-	-	-	-	-
5.	*Anacystis species*	-	+	+	-	-	-	-	-	-	-
6.	*Anacystis cyanea*	-	+	+	+	+	-	-	-	-	-
7.	*Aphanocapsa moutons*	-	-	-	+	+	+	-	-	-	-
8.	*Calothrix species*	+	-	-	-	-	-	-	+	+	+
9.	*Chroococcus species*		+	+	+	+	-	-	-	-	-
10.	*Cylindrosperumum species*	+	-	-	-	-	+	+	+	+	+
11.	*Glaeocapsa species*	-	-	-	-	+	+	-	-	-	-
12.	*Haplosiphon species*	-	+	+	-	-	-	-	-	-	-
13.	*Lungbya species*	+	-	-	-	-	-	+	+	+	+
14.	*Lyngbya limnetica*		+	+	+	+	-	-	-	-	-
15.	*Microchaete species*		+	+	-	-	-	-	-	-	-
16.	*Merismopedia species*		+	+	+	+	-	-	-	-	-
17.	*Nostoc species*	+	-	-	-	-	-	-	+	+	+
18.	*Oscillatoria chlorina*		+	+	+	+	-	-	-	-	-
19.	*Oscillatoria tenuis agardh*	-	+	+	-	-	-	-	-	-	-
20.	*Oscillatoria cuviceps*	-	+	+	+	+	-	-	-	-	-
21	*Oscillatoria limisa*	-	+	+	+	+	+	-	-	-	-
22.	*Oscillatoria princes voucher*		+	+	-	-	-	-	-	-	-
23.	*Oscillatoria rubescens*		+	+	+	+	-	-	-	-	-
24.	*Phormidium species*		+	+	+	+	-	-	-	-	-
25.	*Phormidium tenue menegh*		+	+	+	+	-	-	-	-	-
26	*Spirulina species*		-	-	+	+	+	-	-	-	-

Table 6.9 contd/--

Sl. No.	Algal species	Sampling Stations									
		SS_0	SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_7	SS_8	SS_9
D	**EUGLENOPHYCEAE**										
1.	*Englena species*	-	+	+	+	+	+	-	-	-	-
2.	*Eulgena acus*	-	+	+	+	+	-	-	-	-	-
3.	*Euglena virdes*	-	-	-	+	+	+	-	-	-	-
4.	*Lepocincles ovum*	-	-	+	+	+	+	-	-	-	-
5.	*Phucus longicauda*	-	+	+	+	+	+	-	-	-	-
6.	*Phucus plenronetes*	-	+	+	+	+	+	-	-	-	-
7.	*Trachelomonas species*	-	+	+	+	+	+	-	-	-	-

Sl. No.	Algal species	Sampling Stations									
		SS_0	SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_7	SS_8	SS_9
E	**RHODOPHYCEAE**										
1.	*Batracospermum moniliforme*	-	-	-	-	-	-	+	+	-	-

+ = Presence of algal species at the sampling station

- = Absence of algal species at the sampling station

6.3.2 Trend of Algal Growth

Sampling Station (SS_0) : This is the first sampling station at source of the Tunia river before confluencing with the BRPL's effluent. There are 23 algal species are found which are belong to 14 Bacillariophyceae (60.87%), 4 Chlorophyceae (17.39%) and 5 species of Cyanophyceae species (21.74%). The fluctuating trend of these algal species are in the order of Chlorophyceae < Cyanophyceae < Bacillariophyceae.

Sampling Station (SS_1) : The algal groups has been found in the sampling station (SS_1) are Cyanophyceae, Chlorophycease, Bacillariophyceae and Euglenophyceae. There are 17 species of Cyanophyceae (39.53%), 11 Chlorophyceae (25.58), 10 Bacillariophycease

(23.25%) and 5 species of Euglanophyceae (11.64%). The fluctuating trend of these algal species are in the order of Euglenophyceae < Bacillariophyceae < Chlorophyceae < Cyanophyceae.

Sampling station (SS_2): There are 44 algal species are found of which 17 Cyanophyceae (38.64) 11 Chlorophyceae (25%), 10 Bacillariophyceae (22.74%) and 6 species of Eugleophyceae (13.64%). The fluctuating trend of these algal species in the order of Euglenophycease < Bacillariophyceae < Chlorophyceae < Cyanophyceae.

Sampling Stations (SS_3): There are 49 algal species has been found of which 16 Chlorophycease (32.65%) 14 Cyanophycease (28.58%), 12 Bacillariophyceae (24.49%) and 7 species of Euglenophyceae (14.28%). The fluctuating trend of these algal species in the order of Euglenophyceae < Bacillariophyceae < Cyanophyceae < Chlorophyceae.

Sampling Station (SS_4) : There are 53 algal species are found of which 18 Chlorophyceae (33.96%), 15 Cyanophycease (28.30%), 13 Bacillariophycease (24.53%) and 7 species of Euglenophycease (13.21%). The fluctuating trend of these algal species in the order of Euglenophyceae < Bacillariophyceae < Cyanophyceae < Chlorophyceae.

Sampling Station (SS_5): There are 45 algal species are found of which 17 Chlorophycease (37.78%), 14 Bacillariophycease (31.11%), 8 Cyanophyceae (17.78%) and 6 species of Euglenophyceae (13.30%). The fluctuating trend of these algal species in the order of Englenophyceae < Cyanophyceae < Bacillariophyceae < Chlorophyceae.

Sampling Station (SS_6) : This is the most important station for the algal species because of Rhodophyceae are found and Euglenophyuae are totally disappeared from this station. There are 37 species of algal has been found of which 20 Bacilleriophyceae (54.05%), 12 Chlorophyceae (32.43%), 4 Cyanophyceae (10.82%) and 1 species of Rhodophycae (2.70%). The fluctuating trend of these algal species in the order of Rhodophyceae < Cyanophyceae < Chlorophyceae < Bacillariophyceae.

Sampling Station (SS_7) : There are 43 algal species has been found of which 20 Bacillariophycease (46.52%), 16 Chlorophyceae (37.25%), 6 Cyanophyceae (13.95%) and 1 species of Rhodophyceae (2.32%). The fluctuating trend of these algal species in the order of Rhodophyceae < Cynophyceae < Chlorophyceae < Bacillariophyceae.

Sampling station (SS_8) : There are 40 algal species are identified of which 20 Bacillariophyceae (50%), 14 Chlorophyceae (35%) and 6 species of Cyanophyceae (15%). Only 3 groups of algae are found at this station. The fluctuating trend of these algal species in the order of Cyanophyceae < Chlorophyceae < Bacillariophyceae.

Sampling Station (SS_9): The three algal groups are Bacillariophyceae, Chlorophyceae and Cyanophycease. There are 29 algal species which are 15 Bacillariophycease (51.73%), 8 Chlorophyceae (27.58%) and 6 species of Cyanophyceae (20.6%). The fluctuating trend of these algal species in the order of Cyanophyceae < Chlorophyceae < Bacillariophyceae.

The percentage wise of algal groups/species at the different sampling stations are given in the following Table 6.10.

Table 6.10 : Percentage wise of algal groups at the different sampling stations

S.No.	Algal group/species	Sampling stations									
		SS_0	SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_7	SS_8	SS_9
1.	Bacillariophysceae	60.87	23.25	22.72	24.49	24.53	31.11	54.05	46.52	50.0	51.73
2.	Chlorophyceae	17.39	25.58	25.00	32.65	33.96	37.78	32.43	37.21	35.0	27.58
3.	Cyanophyceae	21.74	39.53	38.64	28.54	28.30	17.78	10.82	13.95	15.0	20.69
4.	Euglenophyceae	-	11.64	13.64	14.28	13.21	13.30	-	-	-	-
5.	Rhodophyceae	-	-	-	-	-	-	2.70	2.32	-	-

6.3.3 Pollutional Behaviour of Algae

Algae are grown both in natural and polluted water but they show different growth and existence as per depend upon the pollution level and nature of the water. The temporal and spatial variation of algae are shown in the following Figure 6.23:

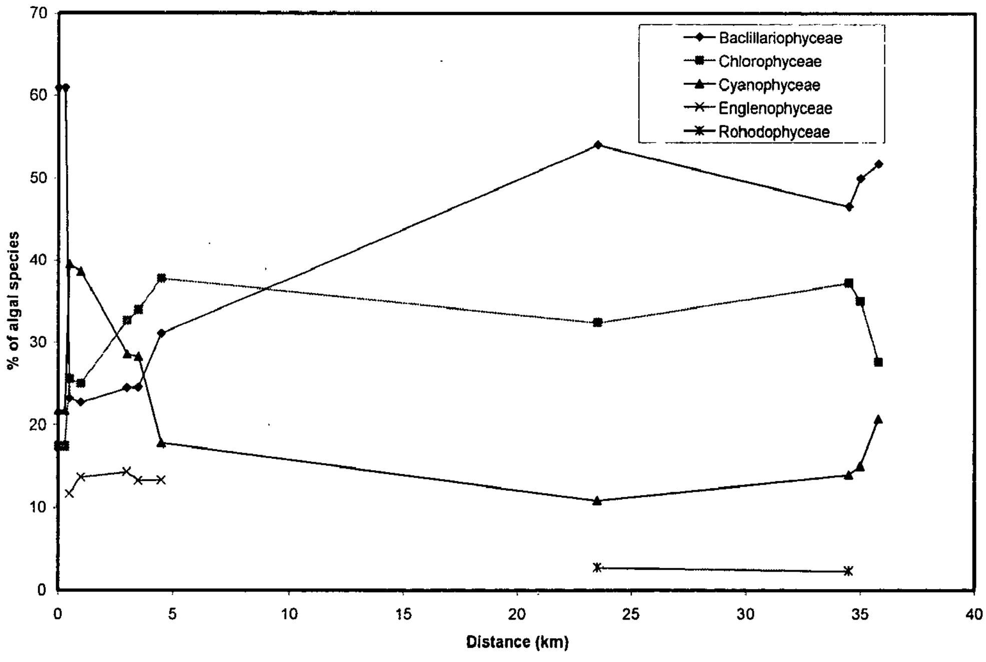

FIG. 6.23: Temporal & spatial variation of algal groups

Bacillariophyceae : Bacillariophyceae are grown in natural as well as in polluted water. More growth has been observed in natural water and gradually depleted by the industrial pollution at the sampling station SS_1 and SS_2. Sewage water influences the growth of population of Bacillariophyceae at the sampling stations SS_3, SS_4, SS_5 and shows gradually upward trend upto the natural water at SS_9. Therefore, there is an upward positive growth rate and species diversity of the Bacillariophyceae are observed in the natural water.

Chlorophyceae : Chlorophyceae indicates the upward trend of population growth from upstream to the downstream of the river. Basically, show more resistance to organic pollution than the natural water. Therefore, Chlorophyceae has been favoured both natural and polluted water.

Cyanophyceae : Cyanophyceae is more resistance to oil and grease and other organic pollution. This group are more grown at the sampling station SS_1 and SS_2 with respect to the other algal species.

Euglenophyceae : Euglenophyceae has been grown in organic polluted water. Their existence are observed at the sampling station from SS_1 to SS_5. As a result, it indicate that Euglenophyceae has a positive upward growth trend in organic polluted water and negative trend in the natural water.

Rohodophyceae : The only species *batrocospermum* of Rohodophyceae group is observed at the sampling station SS_6 and SS_7. Basically Rohodohyceae is grown in the degraded polluting water environment.

6.4 BIOASSAY TEST

Assessment of toxicity in aquatic bodies are conventionally done through the bioassay test using fish as a test organism. Glass aquarium, 100% of river water and size of 5 – 7.5 cm long Labeorohita fish are used for this purposes.

Five nos. of fish are used in each aquarium for 96 hours observation in the river water and determine the percentage of survival rate and mortality rate of fish at different period of exposures in the river water.

After experiment, the percentage of mortality rate of fish is zero at different period of exposures in the river water.

As a results, the percentage of survival rate of fish is 100% at different period of exposures in the river water at all the sampling stations.

No fish are dead during the experimental observation of 96 hours but movement of fish are lessened in the water sample of sampling station SS_1 after 72 hours. Similar observation is also observed in the samples at SS_2. This is happened that the concentration of oil and grease is more at the sampling station SS_1 and SS_2 with compare to the other stations. Regarding to this results, it indicate that the river water is not toxic to fish and other aquatic fauna.

6.5 SUMMARY

The analysis of water has been performed through the water quality analysis, algal analysis and identification and bioassay test.

The water quality analysis are done for physicochemical and bacteriological parameters. The parameters such as physical, organic, mineral and other inorganic parameters are analysed through the physicochemical analysis. The total coliform and faecal coliform are also measured by the bacteriological analysis.

Algal analysis and identification ascertains the algal species of various algal groups at the various sampling stations of the river. It also reveal that the survival existence of algae depend upon as per the pollutional level and nature of the river.

Bioassay test measures the mortality and survival rate of fish asfor ascertaining the toxic level in water of the river.

STATUS OF WATER QUALITY

7.1 GENERAL

The water quality is a most important for a river management programme. The water quality objectives are set with respect to the demands placed on the water resources such as irrigation, drinking, industry, power generation, recreation, fisheries, bathing and even for discharging waste waters together with the fact that all water sources are not necessarily required to meet all potential uses. This has lead to the concept of classification and zoning of water bodies which indicate to meet the requirement of water quality for one or more of the above purposes. The water quality criteria has been established for the designated best use for the particular use.

The water quality of the Tunia river are ascertained by the percentage saturation of dissolved oxygen, biochemical oxygen demand, Central Pollution Control Board and the Indian Standards Institution classification of water resources.

7.2 PERCENTAGE SATURATION OF DISSOLVED OXYGEN CLASSIFICATION

The concentration of dissolved oxygen is a good indicator for the state of pollution of a surface water body in order to its chemical and biological nature. Basically, the rate of deoxygenation reflects the BOD exertion rate in the river water. The reaeration rate is also directly proportional to the DO deficit from the saturation value. With reference to this reason, the dissolved oxygen is used as a good indicator to ascertain the pollutional level in a river water.

The polluted state of a surface water are classified in the following Table 7.1. on the basis of the dissolved oxygen concentration in the river water:

Table 7.1 : Surface water classification by dissolved oxygen level

Sl. No.	Dissolved oxygen (DO)%	Polluted state (PS)	Significance
1.	Below 5	Extremely severe pollution	Water is to be highly turbid and dark grey to black in colour. Bad eggs smell and bottom is to be covered with black sludge. Emit H_2S, NH_3 and CO_2 gases into the air. Some invertebrates can tolerate and bacteria will dominate. No fish will normally be present.
2	5 - 10	Severe pollution	Water is to be grey in colour with a rotten smell. Bottom sludge may be grey but black beneath where oxygen is absent. This water is to be dominated by sewage fungus. Fish are normally absent.
3	10 – 70	Moderate pollution	Water is normally transparent or slightly turbid, uncoloured and odour free. Algae will be grown and produce oxygen. The water is to be characterized by a rich vegetation, fish and invertebrates which can tolerate some pollution.
4	71 – 90	No or slight pollution	The water is clear, fresh and odour free The pollution sensitive invertebrate and fish species will be present.
5	Above 90	Clean	High saturation with DO will be common and very clear water. Most pollution sensitive species is to be present.

The concentration of percentage saturation of dissolved oxygen at the various sampling stations are tabulated against the pollutional status of the Tunia river in the following Table 7.2.

Table 7.2: Status of pollution in the Tunia river by the dissolved oxygen classification

Sl.No.	Sampling Stations	Monsoon				Post Monsoon				Winter				Premonsoon			
		Temp. (^0C)	DO mg/l	DO%	Status of pollution	Temp. (^0C)	DO mg/l	DO%	Status of Pollution	Temp. (^0C)	DO mg/l	DO%	Status of Pollution	Temp. (^0C)	DO mg/l	DO%	Status of Pollution
1	SS_0	26.0	6.70	81.5	NOSLP	25.43	6.83	82.18	NOSLP	19.90	6.58	71.61	NOSLP	26.50	5.80	71.21	NOSLP
2	SS_1	26.50	4.81	59.05	MOP	25.52	4.64	55.92	MOP	20.40	4.36	47.92	MOP	27.20	4.20	52.24	MOP
3	SS_2	26.0	4.25	51.70	MOP	25.50	4.31	51.93	MOP	20.20	4.26	46.64	MOP	27.10	4.10	50.90	MOP
4	SS_3	26.30	3.50	42.81	MOP	25.58	3.70	44.65	MOP	20.52	3.56	39.22	MOP	26.90	3.20	39.58	MOP
5	SS_4	26.50	3.40	41.74	MOP	25.50	3.60	43.37	MOP	20.38	3.48	38.23	MOP	27.30	3.00	37.38	MOP
6	SS_5	26.80	3.20	39.50	MOP	25.50	3.52	42.41	MOP	20.20	3.41	37.33	MOP	27.30	2.95	36.76	MOP
7	SS_6	26.30	4.20	51.37	MOP	25.30	4.20	50.40	MOP	19.68	4.06	43.99	MOP	27.0	3.80	47.08	MOP
8	SS_7	26.00	7.10	86.37	NOSLP	25.10	7.20	86.08	NOSLP	19.48	6.90	74.48	NOSLP	26.8	6.30	77.78	NOSLP
9	SS_8	25.50	7.90	95.18	CL	25.00	7.50	89.49	NOSLP	19.18	7.38	79.20	NOSLP	26.3	7.00	85.62	NOLSP
10	SS_9	24.80	8.25	98.09	CL	24.50	8.40	99.35	CL	19.14	8.37	89.76	NOSLP	26.1	8.20	99.93	CL

NOSLP- No or sliht pollution, MOP = Moderate pollution, CL - clean

On the basis of the above results, the source of the Tunia river is under no or slight pollutional state. The whole Tunia river is facing for moderate pollutional problem. Before confluence with the Champamati river, the water quality of the Tunia river is gradually improving to no or slight pollutional state due to self purification process except in monsoon which show clean sate in order to more dilution of river water by the rain water. The water quality of the Champamati river is clean pollutional status after confluence of the Tunia river except in winter in which the water quality is between the boundary level of the no or slight pollution and clean water.

7.3 BIOCHEMICAL OXYGEN DEMAND CLASSIFICATION

The BOD value can be used as a indicator of river pollution to ascertain the quality of river pollution. The Royal Commission, 1900, U.K. judged the river water quality by the BOD value of the water course. The U.K. Environmental Agency has established a system of river classification used the following BOD range in the Table 7.3 as a bench mark to establish the quality objectives [80].

Table 7.3 : Surface water classification by biochemical oxygen demand (BOD) level

Sl. No.	BOD (mg/l)	Classification / status of pollution
1.	1.0	Very clean
2.	2.0	Clean
3.	3.0	Fairly clean
4.	5.0	Doubtful
5.	10.0	Bad

The water quality of the Tunia river at the various sampling stations has been ascertained on the basis of the above BOD value and tabulated in the Table 7.4 is shown below:

Table 7.4 : Status of Pollution in the Tunia river by biochemical oxygen demand classification

Sl. No.	Sampling station	Monsoon		Postmonsoon		Winter		Premonsoon	
		BOD (mg/l)	Status of pollution	BOD (mg/l)	Status of pollution	BOD (mg/l)	Status of pollution	BOD (mg/l)	Status of pollution
1.	SS_0	2.10	Fairly clean	2.44	Fairly clean	2.42	Fairly clean	3.10	Doubtful
2.	SS_1	8.60	Bad	9.66	Bad	9.78	Bad	11.20	Bad
3.	SS_2	8.62	Bad	9.71	Bad	9.81	Bad	11.50	Bad
4.	SS_3	24.60	Bad	26.67	Bad	27.78	Bad	30.30	Bad
5.	SS_4	25.10	Bad	27.36	Bad	28.68	Bad	32.20	Bad
6.	SS_5	53.10	Bad	52.24	Bad	53.66	Bad	55.50	Bad
7.	SS_6	14.20	Bad	16.50	Bad	17.32	Bad	21.0	Bad
8.	SS_7	12.20	Bad	10.50	Bad	11.24	Bad	16.0	Bad
9.	SS_8	3.30	Doubtful	3.80	Doubtful	4.06	Doubtful	7.50	Bad
10.	SS_9	1.2	Clean	1.20	Clean	1.24	Clean	3.10	Doubtful

The BOD value of the Indian rivers are generally high with compare to the Western countries. This is due to the cause of human and animal bathing, idol immersion, prey and devotion, mass bathing for religious occasion, open faeces, discharge of industrial effluents and untreated sewage water, mixing of ash from crematoria, open faeces, throw of carcassial matter, agriculture and urban run off and other human activities. In view of the above reason, the CPCB has fixed to ascertain the standard value of BOD in the Indian rivers is 2 mg/l for class A water in favour of the designated best use.

7.4 CPCB CLASSIFICATION

The water resources can be classified or zoned depending upon the designated best use of the water. The Central Pollution Control Board (CPCB) along with the State Pollution Control Boards has adopted a scheme of classification and zoining of water resources [34]. Therefore, the water quality criteria for the classification of surface water is given below in the following Table 7.5.

Table 7.5 : Classification and zoining of water bodies (CPCB-1979)

Sl. No.	Designated best use	Nomenclature for the class of water
1.	Drinking water source without conventional treatment but after disinfection	Class A
2.	Out door bathing (organized)	Class B
3.	Drinking water source with conventional treatment followed by disinfection	Class C
4.	Propagation of wild life, fisheries	Class D
5.	Irrigation, industrial cooling and controlled waste disposal	Class E.

The water quality criteria for the above classification is given in the following Table 7.6 for the surface water resources.

Table 7.6 : CPCB standards for classification of inland surface waters

Sl. No.	Parameters	Class of waters				
		A	B	C	D	E
1.	Dissolved oxygen (DO) mg/l (min)	6	5	4	4	-
2.	Biochemical oxygen demand (BOD), mg/l (max)	2	3	3	-	-
3.	Total coliform MPN/100 ml (max)	50	500	5000	-	-
4.	Total dissolved solids (TDS), mg/l (max.)	500	-	1500	-	2100
5.	Chloride, mg/l (max)	250	-	600	-	600
6.	Colour, hazen units (max)	10	300	300	-	-
7.	Sodium absorption ratio (max)	-	-	-	-	26
8.	Boron, mg/l (max)	-	-	-	-	2
9.	Sulphate, mg/l (max)	400	-	400	-	1000
10.	Nitrates, mg/l (max)	20	-	50	-	-
11.	Free ammonia (as NH_3), mg/l (max)	-	-	-	1.2	-
12.	Conductivity at 25^0C micro-mhos/cm (max)	-	-	-	1000	2250
13.	pH value	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
14.	Arsenic (as As), mg/l (max)	0.05	0.02	0.2	-	-
15.	Iron (as Fe) mg/l (max)	0.30	-	50	-	-
16.	Fluorides (as F), mg/l (max)	1.50	1.50	1.50	-	-
17.	Lead (as Pb), mg/l (max)	0.10	-	0.10	-	-
18.	Copper (as Cu), mg/l (max)	1.50	-	1.50	-	-
19.	Zinc (as Zn), mg/l (max)	15	-	15	-	-

If the coliforms are found to be more than the prescribed tolerance limits, the criteria for coliform shall be satisfied if not more than 20% of the samples exceed the tolerance limits specified and not more than 50% samples have values more than 4 times the tolerance limits.

There should be no visible discharge of domestic and industrial wastes into class A water.

In case of Class B and C, the discharge shall be regulated / treated as to ensure the maintenance of the stream standards.

7.5 INDIAN STANDARDS INSTITUTION (ISI) STANDARDS (IS :229,1982)

The parameters for primary water quality criteria for various uses of Inland / surface water as prescribed by the Indian Standards Institution, 1982 is given in the following table 7.7 [12].

Table 7.7 : ISI standards for classification of inland surface waters

Sl. No.	Parameters	Class of waters				
		A	B	C	D	E
1.	Dissolved oxygen (DO), mg/l (min)	6	5	4	4	-
2.	Biochemical oxygen demand (BOD), mg/l (max)	2	3	3	-	-
3.	Total coliform, MPN/100 ml (max)	50	500	5000	-	-
4.	Total dissolved solids, mg/l (max)	500	-	1500	-	2100
5.	Chlorides, mg/l (max)	250	-	600	-	600
6.	Boron, mg/l (max)	-	-	-	-	2
7.	Sulphates, mg/l (max)	400	-	400	-	1000
8.	Nitrates, mg/l (max)	20	-	50	-	-
9.	Free ammonia (NH_3), mg/l (max)	-	-	-	1.20	-
10.	Conductivity at 25^0C micromhos/cm (max)	-	-	-	1000	2250
11	pH	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5

The water quality and classification of the Tunia river water are tabulated for the monsoon 2005, post monsoon 2005, winter 2006 and premonsoon 2006 in the Table 7.8, Table 7.9, Table 7.10 and Table 7.11 by the CPCB and ISI Standards.

Table 7.8: Water quality and classification of the Tunia river water by the CPCB and ISI sandards, monsoon, 2005.

S.No.	Sampling stations	pH	Temp. °C	Turb NTU	Spe. condu.μ mho/cm	DO mg/l	BOD mg/l	COD mg/l	TKN mg/l	Oil & Grease mg/l	Phe. Comps mg/l	Sulphide mg/l	Sulphate mg/l	Chloride mg/l	Fluoride mg/l	Phosphate mg/l	Nitrate mg/l	Amm. Nitrogen mg/l	TDS mg/l	TSS mg/l	Total coliform MPN/100ml	Faecal colifrom MPN/100ml	Class of water CPCB/ISI
1	SS_0	7.30	26.0	13.80	225	6.70	2.10	11.00	1.85	-	-	0.05	0.05	12.80	0.05	3.00	0.08	0.03	95.10	19.00	10,300.00	800.00	A
2	SS_1	7.31	26.50	15.60	610	4.81	8.60	41.22	3.52	3.10	0.188	0.099	18.50	22.10	0.10	0.75	0.85	2.50	172.50	19.90	2,500.00	400.00	E
3	SS_2	7.32	26.00	17.20	430	4.25	8.62	41.30	3.55	3.09	0.187	0.098	19.50	22.20	0.099	0.720	0.830	2.45	166.3	20.3	3000	500	E
4	SS_3	7.25	26.30	26.30	320.50	3.50	24.60	64.70	3.82	2.55	0.154	0.098	20.10	24.45	0.082	0.81	1.20	2.10	185.3	23.23	120000	32500	E
5	SS_4	7.30	26.50	26.90	250.60	3.40	25.10	65.40	3.90	2.7	0.152	0.098	20.60	24.70	0.082	0.850	1.350	1.75	185.8	24.62	82000	28500	E
6	SS_5	7.20	26.80	27.80	230.30	3.20	53.10	108.00	3.95	1.70	0.10	0.097	21.80	29.20	0.089	0.91	1.67	1.54	187.40	55.00	78,000.00	31,500.00	E
7	SS_6	7.25	26.30	31.50	180.50	4.20	14.20	52.20	2.91	1.45	0.10	0.096	20.10	26.30	0.089	0.82	1.10	1.25	155.50	42.30	58,000.00	19,500.00	E
8	SS_7	7.20	26.00	37.90	165.80	7.10	12.20	28.40	2.65	1.20	0.095	0.094	16.50	23.20	0.087	0.690	0.550	0.9	105.7	31.4	50000	13300	D
9	SS_8	730	25.50	39.50	136.30	7.90	3.30	20.10	1.55	1.00	0.09	0.092	11.50	21.20	0.088	0.50	0.30	0.41	84.20	20.00	46,000.00	9,500.00	D
10	SS_9	7.15	24.80	35.60	110.80	8.25	1.20	3.82	1.25	0.10	-	0.10	10.10	7.25	0.10	0.15	0.10	0.20	90.30	12.90	12,500.00	1,150.00	A

Table 7.9: Water quality and classification of the Tunia river water by the CPCB and ISI sandards, postmonsoon, 2005.

S.No.	Sampling stations	pH	Temp. °C	Turb NTU	Spe. condu.µ mho/cm	DO mg/l	BOD mg/l	COD mg/l	TKN mg/l	Oil & Grease mg/l	Phe. Comps mg/l	Sulphide mg/l	Sulphate mg/l	Chloride mg/l	Fluoride mg/l	Phosphate mg/l	Nitrate mg/l	Amm. Nitrogen mg/l	TDS mg/l	TSS mg/l	Total coliform MPN/100ml	Faecal colifrom MPN/100ml	Class of water CPCB/ISI
1	SS_0	7.23	25.43	12.50	230.50	6.83	2.44	10.40	1.80	-	-	0.056	0.056	13.10	0.057	3.20	0.10	0.03	96.50	19.20	10,430	820.00	A
2	SS_1	7.20	25.52	14.06	614	4.64	9.66	42.80	3.58	3.40	0.202	0.144	19.60	23.18	0.114	0.814	0.902	2.60	176.80	20.96	2,400	360.00	E
3	SS_2	7.10	25.50	15.38	448.26	4.31	9.71	43.60	3.47	3.31	0.199	0.143	20.40	23.46	0.114	0.784	0.866	2.52	177.2	21.4	2610	376	E
4	SS_3	7.30	25.58	24.04	315.52	3.70	26.67	67.20	3.76	2.75	0.166	0.136	20.56	25.51	0.095	0.848	1.308	2.104	187.8	34.56	120000	32300	E
5	SS_4	7.40	25.50	24.44	248.50	3.60	27.36	68.65	3.89	2.88	0.167	0.135	21.30	25.81	0.094	0.910	1.494	1.874	187.9	35.87	82500	29500	E
6	SS_5	7.22	25.50	25.24	226.70	3.52	52.24	111.65	4.10	1.80	0.10	0.142	22.10	30.86	0.097	0.944	1.78	1.64	188.20	68.75	780,000	32,000.00	E
7	SS_6	7.20	25.30	30.20	190.20	4.20	16.50	56.50	2.90	1.50	0.10	0.12	20.30	28.20	0.09	0.85	1.20	1.35	160.50	60.10	65,000.00	24,000.00	E
8	SS_7	7.10	25.10	35.50	170.50	7.20	10.50	32.50	2.60	1.40	0.09	0.11	15.20	24.50	0.10	0.730	0.62	0.98	110.8	35.2	52000	16000	D
9	SS_8	7.10	25.00	38.50	140.40	7.50	3.80	21.20	1.50	1.10	0.08	0.10	13.40	20.50	0.10	0.55	0.35	0.45	85.20	30.60	46,000	9,800.00	D
10	SS_9	7.05	24.50	29.50	115.60	8.40	1.20	3.80	1.20	0.06	0.04	0.08	9.50	7.30	0.10	0.10	0.15	0.25	95.00	20.50	11,000	950.00	A

Table 7.10: Water quality and classification of the Tunia river water by the CPCB and ISI sandards, winter - 2006.

S.No.	Sampling stations	pH	Temp. °C	Turb NTU	Spe. condu.µ mho/cm	DO mg/l	BOD mg/l	COD mg/l	TKN mg/l	Oil & Grease mg/l	Phe. Comps mg/l	Sulphide mg/l	Sulphate mg/l	Chloride mg/l	Fluoride mg/l	Phosphate mg/l	Nitrate mg/l	Amm. Nitrogen mg/l	TDS mg/l	TSS mg/l	Total coliform MPN/100ml	Faecal colifrom MPN/100ml	Class of water CPCB/ISI
1	SS_0	7.12	19.9	9.98	231.20	6.58	2.42	11.08	1.84	-	-	0.062	0.058	13.54	0.058	3.54	0.104	0.042	95.72	19.06	8,460	850	A
2	SS_1	6.94	20.40	17.24	637	4.36	9.78	48.70	3.524	3.54	2.28	0.163	20.32	22.66	0.127	0.858	0.944	2.21	177.38	21.36	2,100	360	E
3	SS_2	6.96	20.20	17.90	474	4.26	9.81	48.84	3.444	3.42	2.14	0.147	20.62	23.84	0.127	0.806	0.896	2.16	179.62	21.66	2400	380	E
4	SS_3	7.18	20.52	18.16	322.00	3.56	27.78	68.32	3.574	2.86	1.94	0.142	20.88	25.68	0.116	0.944	1.34	2.034	189.20	35.36	90400	29340	E
5	SS_4	7.28	20.38	18.04	256.60	3.48	28.68	69.44	3.80	2.87	1.84	0.144	21.38	25.78	0.116	1.0	1.522	1.866	188.66	36.26	85040	29500	E
6	SS_5	7.14	20.20	18.62	238.00	3.41	53.66	107.80	4.56	1.92	1.24	0.148	22.18	31.32	0.112	1.36	1.85	1.59	188.78	67.88	72,200	28,540	E
7	SS_6	7.10	19.68	28.34	190.14	4.06	17.32	58.78	3.06	1.78	0.11	0.132	20.14	29.74	0.120	0.968	1.42	1.392	165.70	61.82	62,040	23,200	E
8	SS_7	7.10	19.48	28.20	172.06	6.90	11.24	33.24	2.70	1.52	0.10	0.123	14.54	26.26	0.098	0.826	0.836	1.12	115.78	36.32	51080	14540	D
9	SS_8	7.03	19.18	28.06	143.04	7.38	4.06	22.38	1.50	1.20	0.09	0.113	12.84	21.32	0.093	0.598	0.474	0.678	86.64	30.04	45,540.00	9,140	D
10	SS_9	7.02	19.14	28.10	116.28	8.37	1.24	4.06	1.28	0.063	0.053	0.104	9.24	10.14	0.09	0.266	0.220	0.274	91.78	22.26	10,140	968	A

Table 7.11: Water quality and classification of the Tunia river water by the CPCB and ISI sandards, premonsoon, 2006.

S.No.	Sampling stations	pH	Temp. °C	Turb NTU	Spe. condu.µ mho/cm	DO mg/l	BOD mg/l	COD mg/l	TKN mg/l	Oil & Grease mg/l	Phe. Comps mg/l	Sulphide mg/l	Sulphate mg/l	Chloride mg/l	Fluoride mg/l	Phosphate mg/l	Nitrate mg/l	Amm. Nitrogen mg/l	TDS mg/l	TSS mg/l	Total coliform MPN/100 ml	Faecal colifrom MPN/100ml	Class of water CPCB/ISI
1	SS_0	7.15	26.50	10.50	235.00	5.80	3.10	12.10	2.10	-	-	0.08	0.07	14.50	0.06	3.90	0.15	0.05	101.50	20.10	10,500	1,150	A
2	SS_1	6.75	27.20	18.80	650	4.20	11.20	50.20	3.80	3.65	2.45	0.20	21.20	23.20	0.13	1.10	1.10	2.50	180.60	22.40	2,600	380	E
3	SS_2	6.86	27.10	19.20	500	4.10	11.50	51.80	3.67	3.58	2.31	0.180	21.90	23.80	0.139	1.0	1.0	2.3	182.3	22.6	2900	420	E
4	SS_3	7.15	26.90	20.10	380.00	3.20	30.30	71.80	3.70	3.1	1.95	0.17	22.10	26.56	0.125	0.98	1.51	2.1	193.200	37.8	95800	31200	E
5	SS_4	7.25	27.30	19.90	310.00	3.00	32.20	73.30	3.85	2.95	1.870	0.18	22.70	26.90	0.129	1.10	1.67	1.95	192.5	38.9	90300	31500	E
6	SS_5	7.15	27.30	20.30	270.00	2.95	55.50	110.50	3.95	2.51	1.45	0.165	23.10	33.50	0.121	1.45	1.96	1.70	192.90	68.90	85,000	30,200	E
7	SS_6	7.20	27.00	20.80	220.00	3.80	21.00	61.20	3.62	2.30	0.13	0.145	21.20	31.60	0.12	1.20	1.35	1.41	175.60	62.30	65,000	26,000	E
8	SS_7	7.15	26.80	20.80	190.00	6.30	16.00	35.30	3.20	1.90	0.11	0.136	16.30	28.50	0.099	1.100	1.20	1.00	135.8	38.5	54000	16500	D
9	SS_8	7.10	26.30	21.10	155.00	7.00	7.50	24.20	1.80	1.65	0.10	0.123	13.50	23.70	0.096	1.0	0.80	0.55	96.30	32.40	46,800	10,200	D
10	SS_9	7.05	26.10	21.30	125.00	8.20	3.10	5.10	1.50	0.12	0.09	0.11	10.50	12.80	0.091	0.50	0.600	0.35	98.80	24.80	11,500	1,060.00	A

7.6 COMPARISON OF QUALITY

The water quality of the Tunia river are compared with the four classification of water such as percentage saturation of dissolved oxygen, biochemical oxygen demand, Central Pollution Control Board and Indian Standards Institution classification. Therefore, the water quality of the Tunia river at the various sampling station are tabulated in the Table 7.12 against the aforesaid classification in respect of the water resources.

Table 7.12 : The overall water quality of the Tunia river by DO%, BOD, CPCB and ISI standards

Sl. No.	Sampling station	DO%	BOD	CPCB/ISI (Class of Waters)
1.	SS_0	NOSLP.	Fairly clean	A
2.	SS_1	MOP	Bad	E
3.	SS_2	MOP	Bad	E
4.	SS_3	MOP	Bad	E
5.	SS_4	MOP	Bad	E
6.	SS_5	MOP	Bad	E
7.	SS_6	MOP	Bad	E
8.	SS_7	NOSLP	Bad	D
9.	SS_8	NOSLP	Doubtful	D
10	SS_9	Clean	Clean	A

NOSLP = No or slight pollution
MOP = Moderate pollution

The above results has been discussed on the following heads as:

7.6.1 Reach Between the Source and Sampling Station (SS_8)

7.6.1.1 Class A water

The water quality of the Tunia river at the sampling station SS_0, source of the Tunia river is under the class A water as per the CPCB and ISI classification. BOD value is slightly high than the prescribed limits. Other parameters are within the permissible limit except total coliform and faecal coliform. Basically, these coliforms are high in Assam in all the river due to favourable climate for coliforms and discharge of sewage to the river without treatment.

The parameters such as lead, copper, zinc, arsenic, iron etc. are not create any pollutional problem in the river water because of their concentration are very low. The arsenic is not found in the river water and average concentration of zinc 0.05, copper 0.05, lead 0.053 and iron 0.54 mg/l are found in water which are less than the prescribed standards as specified by the CPCB and ISI.

7.6.1.2 Class D water

The water of the sampling station, SS_7 and SS_8 are degraded form of polluted water. The CPCB and ISI ascetain the D class of water for propagation of wild life and fisheres at the said sampling stations. The percentage saturation of dissolved oxygen classification indicates no or slight pollution of water at the sampling station SS_7 and SS_8. The biochemical oxygen demand classification reveals that bad for SS_7 and doubtful for SS_8 class of polluted water at the said sampling stations.

7.6.1.3 Class E water

The water quality of the other sampling stations such as SS_1, SS_2, SS_3, SS_4, SS_5 and SS_6 has been ascertained under the class E water as per the CPCB or ISI classification in which water can be used for irrigation, industrial cooling and controlled waste water disposal. Similarly, BOD and percentage saturation of DO classification indicates the bad and moderate pollution of water at the above sampling stations respectively.

7.6.2 After Confluence

After confluence of the Tunia river with the Champamati river, the water quality of the Champamati river at the sampling station SS_9 is class A water which is a drinking water source without conventional treatment but after disinfection as per the the CPCB and ISI classification. Similarly, the BOD and DO classification indicate that the water quality is clean at the sampling station, SS_9 of the Champamati river.

7.7 SUMMARY

The water quality of the Tunia river has been ascertained by the percentage saturation of dissolved oxygen, biochemical oxygen demand, CPCB and ISI classification for the designated best use. All the four classification indicate that the Tunia river is under moderate organic pollution and the water can be used for E class water as irrigation, industrial cooling and controlled waste disposal including the D class of water for propagation of wild life and fisheries.

CHAPTER – 8

WATER QUALITY INDEX

8.1 GENERAL

An index is a means deviced to reduce a large quantity of data down to a simplest form. Water Quality Index (WQI) is a mathematical aggregation of two or more indicators in some fashion. Basically, it is simply a numerical value having no units and reflects some environmental attribute. Various ranges of the WQI may be used to classify the quality of water for a given use into various classes such as excellent, good, satisfactory, poor and unacceptable.

One more type of water quality indices do exist in the pollution literature i.e. Biological Water Quality Indices. C.M. Palmer has developed to ascertain the water quality. The biological indices are generally developed after evaluating water quality in terms of its impact on aquatic life in some form.

Considering the evaluation of water quality index of the Tunia river, the National Sanitation Foundation Water Quality Index (NSF WQI) and Palmer's Algal Index are applied to evaluate the water quality.

8.2 NATIONAL SANITATION FOUNDATION WATER QUALITY INDEX

Brown et al. (1970) had presented a water quality index similar in structure to Horton's index. It is also called National Sanitation Foundation Water Quality Index (NSFWQI) [13].

It is calculated after aggregating the sub indices for 9 parameters as weighted sum, using the following equation.

$$\text{NSFWQI} = \sum_{i=1}^{n} W_i Q_i$$

The weights for 9 parameters are given in the Table 8.1.

Table 8.1 : Parameters and their weights for NSFWQI

Parameters	Weights
Dissolved oxygen	0.17
Faecal coliform	0.15
pH	0.12
BOD	0.10
Nitrates	0.10
Phosphates	0.10
Temperature	0.10
Turbidity	0.08
Total solids	0.08
Total	1.00

A decreasing scale, 0 – 100 is used for expressing the water quality index. A system of reporting NSFWQI which relates the index values to 5 discriptor words and colours was also suggested by Mechelland et al. (1976) as shown in the following Table 8.2.

Table 8.2 : Descriptor words and colours suggested for reporting NSFWQI

Discriptor words	Very bad	Bad	Medium	Good	Excellent
Numerical range of index	0 – 25	26 – 50	51 – 70	71 – 90	91 – 100
Colour	Red	Orange	Yellow	Green	Blue

The sub index functions of all parameters are shown in figures 8.1 to 8.9.

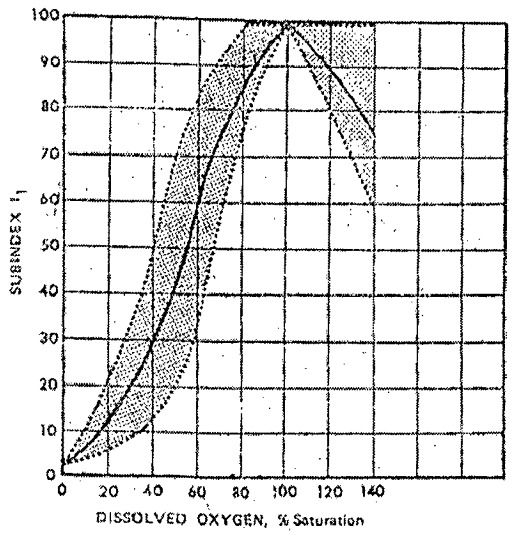

FIG.8.1: Sub index function for DO in the NSF WQI[9] (For DO>140%, I_1=50.)

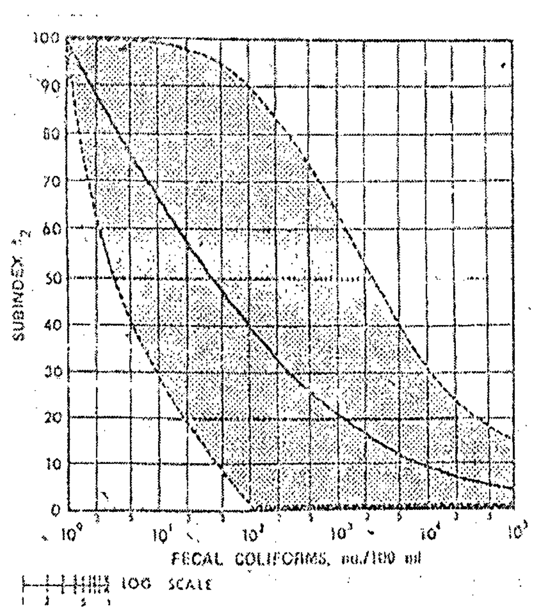

FIG. 8.2. Subindex function for faecal coliforms (average number of organisms per 100 ml) in the NSF WQI[9] (For fecal coliforms > 10^5/100 ml, I_2 = 2

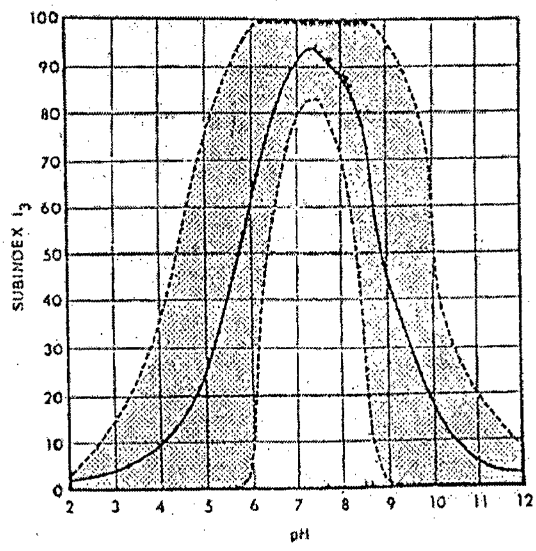

FIG. 8.3. Subindex function for pH in the NSF WQI[9].

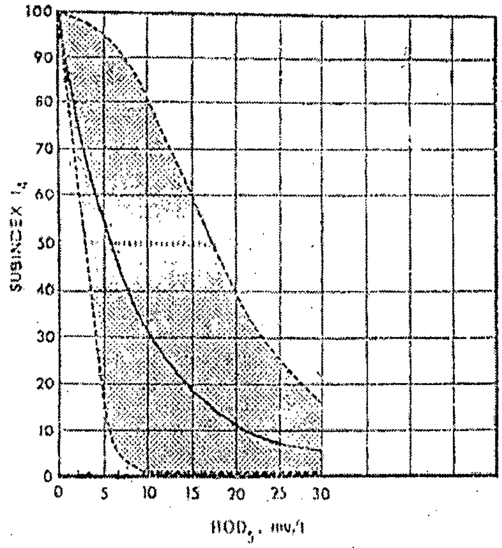

FIG. 8.4: Subindex function for BOD_5 in the NSF WQI[9]
(For BOD_5> 30 mg/l, I_4 = 2.)

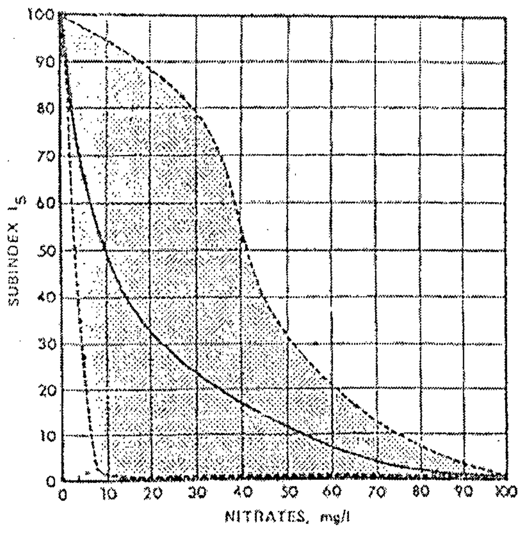

FIG.8.5. Subindex function for nitrates in the NSF WQI[9] (For nitrates >100 mg/l, I_5 =1.)

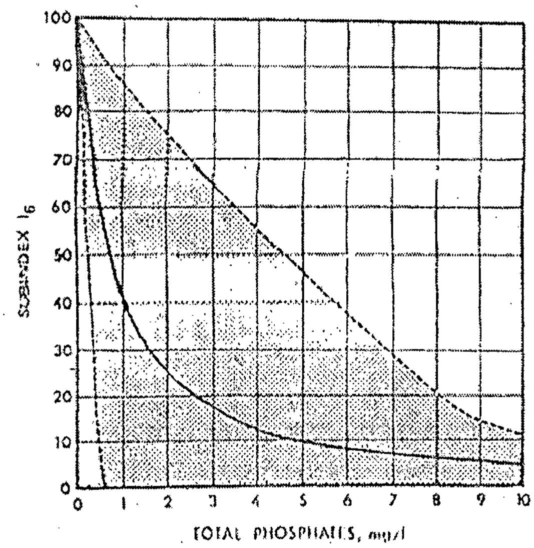

FIG.8.6. Subindex function for total phosphates in the NSF WQI[9] (For total phosphates >100 mg/l, I_6 =2.)

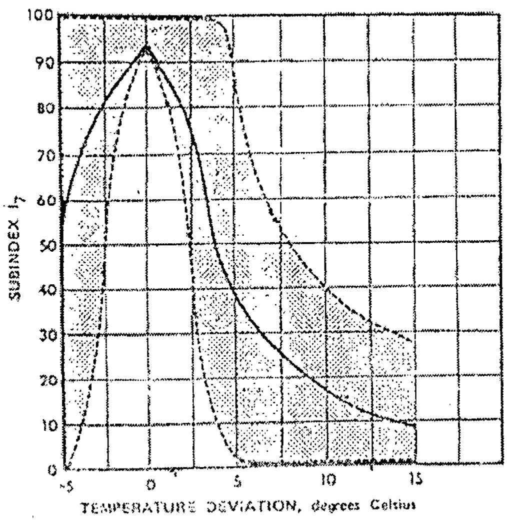

FIG. 8.7: Subindex function for temperature deviation from equilibrium (ΔT) in the NSF WQI[9] (For $\Delta T > 15^0C$, $I_7 = 5$.)

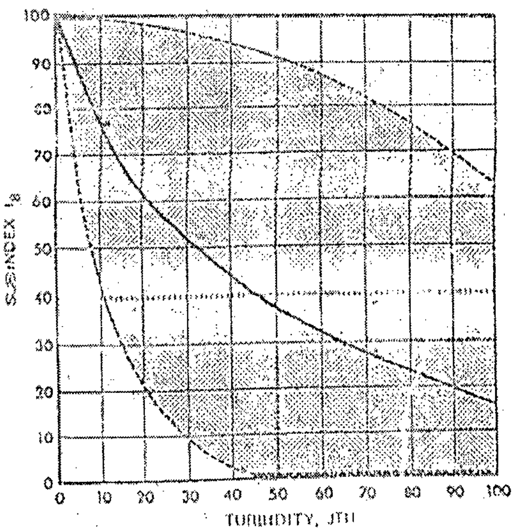

Fig.8.8: Subindex function for turbidity (Jackson Turbidity Units) in the NSF WQI[9] (For turbidity >100 JTU, $I_8 = 5$.)

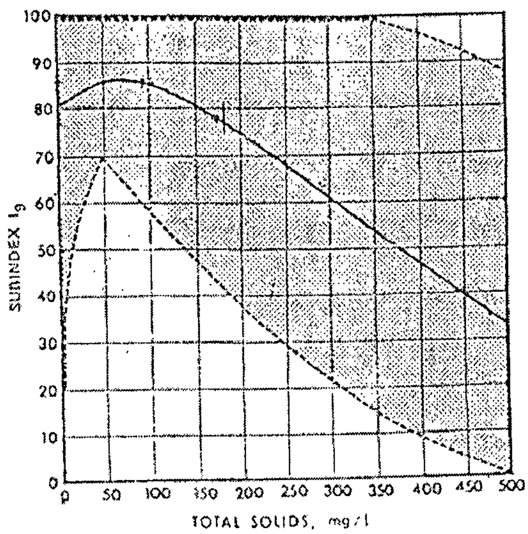

Fig. 8.9: Subindex function for total solids in the in the NSF WQI[9] (For total solids >500 mg/l, $I_9 = 20$.)

The NSFWQI is most commonly employed easy to use index. Most of the state in the USA has modified it to suit their requirement and standards. Higher value of the index indicate better water quality of the river.

The Council of Environmental Quality had proposed the following five criteria for the WQI formulation.

1. It should facilitate communication of environmental quality information to the public.
2. It would be readily derived from available monitoring data.
3. It should strike a balance between over simplification and complex technical conceptualization.
4. It should impart an understanding of significance of data represented.
5. It would be objectively designed but amenable to comparison with expert judgement so that their validity can be assessed.

The NSFWQI has confirmed all the above five criteria. This index is most widely accepted to evaluate the water quality index instead of many water quality indices developed so far. The NSFWQI has got the effectiveness and flexibility, while it is simple to formulate. It indicate higher value of the index is to be better water quality.

The water quality index of the Tunia river at the various sampling stations has been calculated by the NSFWQI in Table 8.3, Table 8.4, Table 8.5 and Table 8.6 for the monsoon, postmonsoon, winter and premonsoon period respectively.

Table 8.3: Calculation of NSFWQI for monsoon, 2005

Sl.No.	Parameters (Q)	Weights (w)	SS_0			SS_1			SS_2			SS_3			SS_4			SS_5			SS_6			SS_7			SS_8			SS_9		
			Q_0	I_0	WI_0	Q_1	I_1	WI_1	Q_2	I_2	WI_2	Q_3	I_3	WI_3	Q_4	I_4	WI_4	Q_5	I_5	WI_5	Q_6	I_6	WI_6	Q_7	I_7	WI_7	Q_8	I_8	WI_8	Q_9	I_9	WI_9
1	pH	0.12	7.30	93	11.16	7.31	93.1	11.17	7.32	93.15	11.18	7.25	93.5	11.22	7.3	93	11.16	7.2	94	11.28	7.25	93.5	11.22	7.2	94	11.28	7.3	93	11.16	7.15	92.5	11.1
2	Temp.	0.10	0.00	93	9.3	0.5	91.5	9.15	0	93	9.3	0.3	92	9.2	0.5	91.5	9.15	0.8	88	8.8	0.3	92	9.2	0	93	9.3	0.5	91	9.1	-1.2	88.5	8.85
3	Turb	0.08	13.80	70	5.6	15.6	69	5.52	17.2	67	5.36	26.3	58	4.64	26.9	57.8	4.62	27.8	55	4.4	31.5	50	4	37.9	47	3.76	39.5	45	3.6	35.6	48	3.84
4	DO(%)	0.17	81.50	89	15.13	59.05	58	9.86	51.7	42	7.14	42.81	31.5	5.36	41.74	31	5.27	39.5	29.5	5.02	51.37	41	6.97	86.37	90	15.3	95.18	95	16.15	98.09	98	16.6
5	BOD	0.10	2.10	75	7.5	8.6	37	3.7	8.62	37.1	3.71	24.6	7.5	0.75	25.1	7	0.7	53.1	2	0.2	14.2	20	2	12.2	28.4	2.84	3.3	70	7	1.2	92	9.2
6	TN	0.10	0.08	98.0	9.8	0.85	92	9.2	0.83	91.8	9.18	1.2	88	8.8	1.35	87.3	8.73	1.67	72	7.2	1.1	90	9	0.55	93	9.3	0.3	94	9.4	0.1	95	9.5
7	TP	0.10	3.0	18.50	1.85	0.75	58	5.8	0.72	58.3	5.83	0.81	52	5.2	0.85	53	5.3	0.91	43	4.3	0.82	46	4.6	0.69	58.9	5.89	0.5	65	6.5	0.15	78	7.8
8	TS	0.08	114.10	83.50	6.68	192.4	75.5	6.04	186.6	75	6	208.53	73	5.84	210.42	72.5	5.8	242.4	70	5.6	197.8	75	6	137.1	82	6.56	104.2	85	6.8	103.2	85.03	6.8
9	FC	0.15	800	22	3.3	400	52	7.8	500	48	7.2	32500	5.1	0.765	28500	5.2	0.78	31500	5.05	0.76	19500	6.5	0.98	13300	8.5	1.26	9500	10	1.5	1150	18.5	2.775
	Total				70.32			68.24			67.6			51.76			51.51			47.56			53.97			65.49			71.21			76.53

Q= Parameters, W = Weights, I = subindex, WI = Water quality index of parameter

Table 8.4: Calculation of NSFWQI for postmonsoon, 2005

Sl.No.	Parameters (Q)	Weights (w)	SS_0			SS_1			SS_2			SS_3			SS_4			SS_5			SS_6			SS_7			SS_8			SS_9		
			Q_0	I_0	WI_0	Q_1	I_1	WI_1	Q_2	I_2	WI_2	Q_3	I_3	WI_3	Q_4	I_4	WI_4	Q_5	I_5	WI_5	Q_6	I_6	WI_6	Q_7	I_7	WI_7	Q_8	I_8	WI_8	Q_9	I_9	WI_9
1	pH	0.12	7.23	96	11.52	7.2	92.9	11.15	7.1	92.5	11.1	7.3	93.5	11.22	7.4	92.50	11.10	7.22	93.1	11.17	7.20	92.90	11.15	7.1	92.5	11.1	7.10	92.5	11.1	7.05	94	11.28
2	Temp.	0.10	0.00	93	9.3	0.09	92.5	9.25	0.07	92.7	9.27	0.15	90	9	0.07	92.7	9.27	0.07	92.7	9.27	-0.30	91.5	9.15	-0.33	90.5	9.05	-0.43	89.8	8.98	-0.93	88.5	8.85
3	Turb	0.08	12.50	70	5.6	14.06	67	5.36	15.38	65	5.2	24.04	55.5	4.44	24.44	55.3	4.42	25.24	54	4.32	30.2	50.1	4.01	35.50	47	3.76	38.5	46.2	3.7	29.5	52	4.16
4	DO(%)	0.17	82.18	87.5	14.86	55.92	43	7.31	51.93	40.5	6.89	44.65	38.5	6.55	43.37	345	5.87	42.41	32.1	5.46	50.40	40.1	6.82	86.08	90.1	15.32	89.49	91	15.47	99.35	99	16.83
5	BOD	0.10	2.44	75	7.5	9.66	33	3.3	9.71	31.5	3.15	26.67	7.5	0.75	27.36	7.2	0.72	52.24	2	0.2	16.5	18.5	1.85	10.50	30.1	3.01	3.8	69	6.9	1.2	92	9.2
6	TN	0.10	0.1	96.0	9.6	0.902	94.5	9.45	0.866	94.8	9.48	1.308	91	9.1	1.494	90	9	1.78	89	8.9	1.2	91.5	9.15	0.62	95.6	9.56	0.35	96.1	9.61	0.15	95.9	9.59
7	TP	0.10	3.2	16.50	1.65	0.814	47.1	4.71	0.784	50	5	0.848	45	4.5	0.910	43	4.3	0.944	42.5	4.25	0.85	46	4.6	0.730	51	5.1	0.55	54	5.4	0.1	88	8.8
8	TS	0.08	115.70	83.50	6.68	197.76	78.5	6.28	198.34	76.2	6.1	223.36	72	5.76	223.77	71.9	5.75	256.95	67.5	5.40	220.6	72.1	5.77	146	82	6.56	115.8	83.5	6.68	115.5	83.6	6.69
9	FC	0.15	820	22	3.3	360	29.5	4.43	376	30	4.5	32300	7.45	1.12	29500	8	1.2	32000	7.5	1.13	24000	8.1	1.23	16000	8.5	1.28	9800	10	1.5	950	21	3.15
	Total				70.01			61.24			60.69			52.44			51.63			50.10			51.73			64.74			69.34			78.55

Q= Parameters, W = Weights, I = subindex, WI = Water quality index of parameter

Table 8.5: Calculation of NSFWQI for winter, 2006

Sl.No.	Parameters (Q)	Weights (w)	SS_0			SS_1			SS_2			SS_3			SS_4		
			Q_0	I_0	WI_0	Q_1	I_1	WI_1	Q_2	I_2	WI_2	Q_3	I_3	WI_3	Q_4	I_4	WI_4
1	pH	0.12	7.12	92	11.04	6.94	90.1	10.81	6.96	90.15	10.82	7.18	92.2	11.06	7.28	93.00	11.16
2	Temp.	0.10	0.0	93	9.30	0.5	92.50	9.25	0.3	92.6	9.26	0.62	91	9.1	0.48	91.8	9.18
3	Turb	0.08	9.98	77.10	6.17	17.24	66.3	5.3	17.9	66.1	5.29	18.16	66	5.28	18.04	66.05	5.28
4	DO(%)	0.17	71.61	76.50	13	47.92	40	6.8	46.64	39.5	6.72	39.22	27.5	4.68	38.23	27.3	4.64
5	BOD	0.10	2.42	75.0	7.5	9.78	31	3.1	9.81	30.9	3.09	27.78	6.5	0.65	28.63	6	0.6
6	TN	0.100	0.104	94.0	9.4	0.944	85	8.5	0.896	89	8.9	1.34	78	7.8	1.522	77	7.7
7	TP	0.10	3.54	15.60	1.56	0.858	48	4.8	0.806	48.5	4.85	0.944	43	4.3	1.0	40	4
8	TS	0.8	114.78	84.0	6.72	198.74	75.5	6.04	201.28	75.4	6.03	224.56	71	5.68	224.92	5.67	5.67
9	FC	0.15	850	23.0	3.45	360	29	4.35	380	28.7	4.3	29340	6.5	0.96	29500	6.45	0.98
	Total				68.14			58.95			59.26			49.51		49.21	49.21

Sl.No.	Parameters (Q)	Weights (w)	SS_5			SS_6			SS_7			SS_8			SS_9		
			Q_5	I_5	WI_5	Q_6	I_6	WI_6	Q_7	I_7	WI_7	Q_8	I_8	WI_8	Q_9	I_9	WI_9
1	pH	0.12	7.14	92.19	11.06	7.10	91.99	11.04	7.10	91.99	11.04	7.03	90.10	10.81	7.02	90.09	10.81
2	Temp.	0.10	0.3	92.6	9.26	-0.22	91.0	9.10	-0.42	90.5	9.05	-0.72	90.20	9.02	-0.76	90.15	9.015
3	Turb	0.08	18.62	63	5.04	28.34	52	4.16	28.20	52.2	4.18	28.06	52.3	4.18	28.1	52.35	4.19
4	DO(%)	0.17	37.33	27.10	4.61	43.99	36	6.12	74.48	76	12.92	79.2	87	14.79	89.76	98	16.66
5	BOD	0.10	53.66	2.0	0.2	17.32	13.5	1.35	11.24	29	2.9	4.06	64	6.4	1.24	88	8.8
6	TN	0.100	1.85	76.5	7.65	1.42	77.8	7.78	0.836	87	8.7	0.474	92	9.2	0.22	93	9.3
7	TP	0.10	1.36	32	3.2	0.968	41.5	4.15	0.826	53	5.3	0.598	64	6.4	0.266	72	7.2
8	TS	0.8	256.66	67.5	5.40	227.52	72.5	5.8	152.4	80	6.4	116.68	83.9	6.71	114.04	83.95	6.72
9	FC	0.15	28540	6.55	0.98	23200	7.0	1.05	145.40	9.5	1.43	9140	9.9	1.49	968	21.5	3.23
	Total				47.40			50.55			61.92			69			75.925

Q= Parameters, W = Weights, I = subindex, WI = Water quality index of parameter

Table 8.6: Calculation of NSFWQI for premonsoon, 2006

Sl.No.	Parameters (Q)	Weights (w)	SS_0			SS_1			SS_2			SS_3			SS_4		
			Q_0	I_0	WI_0	Q_1	I_1	WI_1	Q_2	I_2	WI_2	Q_3	I_3	WI_3	Q_4	I_4	WI_4
1	pH	0.12	7.15	91.50	10.98	6.75	87.50	10.50	6.86	88.10	10.60	7.150	91.50	10.98	7.25	92.20	11.10
2	Temp.	0.10	0.0	93	9.30	0.70	90.00	9.0	0.60	91.20	9.12	0.40	91.5	9.15	0.8	89.5	8.95
3	Turb	0.08	10.50	76.50	6.12	18.80	64.0	5.12	19.20	62.10	4.97	20.1	61.5	4.92	19.9	62	4.96
4	DO(%)	0.17	71.21	72.00	12.24	52.24	41.50	7.06	50.9	40.50	6.89	39.58	29.5	5.02	37.38	23.4	3.98
5	BOD	0.10	3.10	68.0	6.8	11.20	28.3	2.83	11.50	28.00	2.8	30.3	2.0	0.2	32.2	2	0.2
6	TN	0.100	0.15	93.5	9.35	1.10	88	8.8	1.0	90	9.0	1.51	86.0	8.6	1.67	85.5	8.55
7	TP	0.10	3.90	13.30	1.33	1.10	38	3.8	1.0	42	4.2	0.98	43.5	4.35	1.1	38	3.8
8	TS	0.08	121.60	83.0	6.64	203	72.8	5.82	204.9	72.70	5.81	231	70	5.6	231.4	69.99	5.6
9	FC	0.15	1150.0	18.50	2.78	380	23.10	3.47	420	22.8	3.42	31200	6.2	0.93	31500	6.1	0.915
	Total				65.54			56.4			56.81			49.75			48.06

Sl.No.	Parameters (Q)	Weights (w)	SS_5			SS_6			SS_7			SS_8			SS_9		
			Q_5	I_5	WI_5	Q_6	I_6	WI_6	Q_7	I_7	WI_7	Q_8	I_8	WI_8	Q_9	I_9	WI_9
1	pH	0.12	7.15	91.5	10.98	7.20	92.50	11.1	7.15	91.5	10.98	7.10	91.00	10.92	7.05	90.5	10.86
2	Temp.	0.10	0.8	89.5	8.95	0.50	90.6	9.06	0.3	90.9	9.09	-0.2	91.50	9.15	-0.4	90.0	9.0
3	Turb	0.08	20.3	61.3	4.9	20.8	60.1	4.81	20.80	60.1	4.81	21.1	59.4	4.75	21.3	59.1	4.73
4	DO(%)	0.17	36.76	37.10	6.31	47.08	39.5	6.72	77.78	81	13.77	85.62	87	14.79	99.93	93	15.81
5	BOD	0.10	55.5	2.0	0.2	21	10.1	1.01	16.00	18.5	1.85	7.5	41.5	4.15	3.1	68	6.8
6	TN	0.100	1.96	78	7.8	1.55	85.99	8.599	1.2	87.3	8.73	0.8	89.5	8.95	0.6	91.6	9.16
7	TP	0.10	1.45	31	0.31	1.2	35.5	3.55	1.100	38	3.8	1	42	4.2	0.5	62	6.2
8	TS	0.08	261.8	62	4.96	237.9	69.2	5.54	174.3	78	6.24	128.7	82.5	6.6	123.6	82.9	6.63
9	FC	0.15	30200	6.3	0.96	26000	6.5	0.98	16500	6.8	1.02	10200	6.85	1.03	1060	20.5	3.08
	Total				48.16			51.37			60.29			64.54			72.37

Q= Parameters, W = Weights, I = subindex, WI = Water quality index of parameter

8.2.1 Comparison of Water Quality

The water quality index of the Tunia river for 4 sasons such as monsoon, postmonsoon, winter and premonsoon at the various sampling stations are tabulated in the following Table 8.7 to ascertain the water quality at the respective stations.

Table 8.7 : Water quality index of the Tunia river in monsoon, postmonsoon, winter and premonsoon

Sl. No.	Sampling station	Monsoon			Postmonsoon			Winter			Premonsoon		
		DW	IV	C	DW	IV	C	DW	IV	C	DW	IV	C
1	SS_0	G	70.32	G	G	70.01	G	M	68.14	Y	M	65.54	Y
2	SS_1	M	68.24	Y	M	61.24	Y	M	58.95	Y	M	56.40	Y
3	SS_2	M	67.60	Y	M	60.69	Y	M	59.26	Y	M	56.81	Y
4	SS_3	M	51.76	Y	M	52.44	Y	B	49.51	O	B	49.75	O
5	SS_4	M	51.51	Y	M	51.63	Y	B	49.21	O	B	48.06	O
6	SS_5	B	47.56	O	M	50.10	Y	B	47.40	O	B	48.16	O
7	SS_6	M	53.97	Y	M	51.73	Y	M	50.55	Y	M	51.37	Y
8	SS_7	M	65.49	Y	M	64.74	Y	M	61.20	Y	M	60.29	Y
9	SS_8	G	71.21	G	M	69.34	Y	M	69	Y	M	64.54	Y
10	SS_9	G	76.53	G	G	78.5	G	G	75.92	G	G	72.37	G

DW = Discriptor words, IV = Index value, C = Colour, VB = Very bad, B = Bad, M = Medium, G = Good, E = Excellent, R = Red, O = Orange, Y = Yellow, G = Green, B = Blue

The temporal and spatial variation of the NSFWQI has been shown in the following figure 8.10.

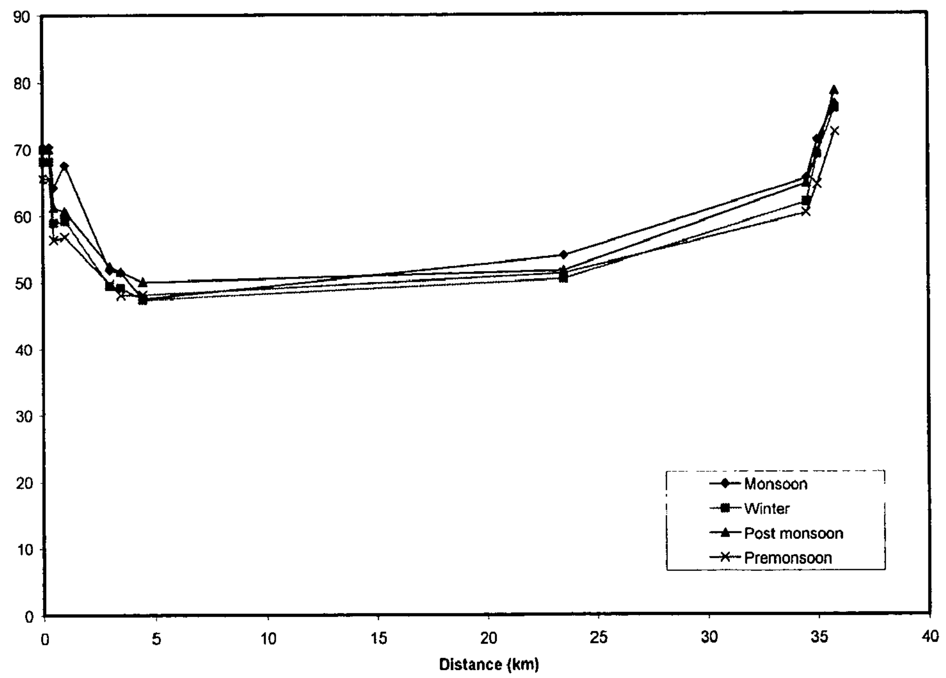

FIG. 8.10 : Temporal and spatial variation of NSFWQI

8.2.1.1 Good quality of water

The good quality of water has been found at the sampling station SS_9 in all the seasons, and at SS_0 for monsoon and postmonsoon period respectively. Good quality of water is also observed at SS_8 in the monsoon only due to heavy rainfall.

8.2.1.2 Medium quality of water

The medium quality of water has been observed at the sampling stations SS_1, SS_2, SS_6 and SS_7 in all the seasons and at SS_3 and SS_4 in monsoon and postmonsoon period respectively. Only medium quality of water is found in postmonsoon at SS_5. It is also found at SS_8 except for monsoon period.

8.2.1.3 Bad quality of water

The bad quality of water are found at SS_5 in monsoon, winter and pre-monsoon and at SS_3 and SS_4 in both winter and pre-monsoon season respectively.

The excellent and very bad water quality are not found in along all the sampling stations of the Tunia river.

8.3 PALMER'S ALGAL INDEX

C.M. Palmer has developed two indices based on algal data for rating organic pollution of water bodies. The indices are:

Palmer's algal genus index

Palmer's algal species index.

8.3.1 Palmer's Algal Genus Index

Palmer listed 20 algal genera which are more tolerant to organic pollution and a number is assigned to each of them depending upon their relative tolerance to organic pollution. The algae are identified and the genera present from the list are noted. The assigned number scored by each genus are totaled to get the value of algal genus index. Palmer has mentioned the pollution index of algal genera in the Table 8.8.

Table 8.8 : Pollution index of algal genera

Sl. No.	Genera	Pollution index	Sl. No.	Genera	Pollution index
1.	*Anacysitis (microcystis)*	1	11	*Micractinium*	1
2	*Ankistrodesmus*	2	12	*Navicula*	3
3.	*Chlamydomonas*	4	13.	*Nitzschia*	3
4.	*Chlorella*	3	14.	*Oscillatoria*	4
5.	*Closterium*	1	15.	*Pandorina*	1
6.	*Cyclotella*	1	16.	*Phacus*	2
7.	*Euglena*	5	17.	*Phormidium*	1
8.	*Gomphonema*	1	18.	*Scenedeomus*	4
9.	*Lepocinclis*	1	19.	*Stigeoclonium*	2
10.	*Melosira*	1	20.	*Synedra*	2

8.3.2 Palmer's Algal Species Index

Palmer listed 20 algal species which are more tolerant to organic pollution and a number is assigned to each of them depending upon their relative tolerance to organic pollution. The assigned number scored by each species are totaled to get the value of algal species index. Palmer has mentioned the pollution index of algal species in the Table 8.9.

Table 8.9 : Pollution index of algal species

Sl. No.	Algal species	Pollution indiex	Sl. No.	Algal species	Pollution index
1.	*Ankistrodesmus falcatus*	3	11.	*Nitzschira palea*	5
2.	*Arthrospira jenneri*	2	12.	*Osllatoria chlorina*	2
3.	*Chlorella vulgairs*	2	13.	*Oscillatoria limisa*	4
4.	*Cyclotalla meneghiniana*	2	14.	*Oscillatoria princes*	1
5.	*Euglena gracilis*	1	15.	*Oscillatoria putrida*	1
6.	*Euglena virdes*	6	16	*Oscillatoria tenuis*	4
7.	*Gomphonema parvulum*	1	17.	*Pandorina morum*	3
8.	*Melosira varians*	2	18.	*Scenedesmus quadricauda*	4
9.	*Navicula cryptocephala*	1	19.	*Stigeoclonium tenue*	3
10.	*Nitzschia acicularis*	1.	20.	*Synedra ulna*	3

8.3.3 Pollution Index Scale

The Palmer pollution index scale is mentioned in Table 8.10.

Table 8.10 : Palmer pollution index scale

Pollution index	Status of pollution
< 15	Very light organic pollution
15 to 20	Organic pollution
> 20	High organic pollution

8.3.4 Algal Genus Index

Regarding to the algal genus index in the Tunia river, the pollution index of the Tunia river at the various sampling stations has been tabulated in the following Table 8.11 for ascertaining the pollutional status of the said river.

Table 8.11 : Pollution tolerant genera of algae in the different sampling stations of the Tunia river

Sl. No.	Algal genera	Sampling Stations									
		SS_0	SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_7	SS_8	SS_9
1.	*Anacystis*	-	1	1	1	1	1	-	-	-	-
2	*Anabaena*	1	1	1	1	1	1	1	1	1	1
3	*Ankistrodesmus*	-	2	2	2	2	2	2	2	2	-
4	*Chlamydomonas*	-	4	4	4	4	-	-	-	-	-
5	*Clostarium*	-	1	1	1	1	1	1	1	1	-
6	*Cyclotella*	1	1	1	1	1	1	1	1	1	1
7	*Chlorella*	-	3	3	3	3	3	-	-	-	-
8	*Euglena*	-	5	5	5	5	5	-	-	-	-
9	*Gomphonema*	-	1	1	1	1	1	1	1	-	-
10.	*Lipocinclis*	-	-	1	1	1	1	-	-	-	-
11	*Melosira*	-	-	-	-	-	-	1	1	1	1
12	*Navicula*	-	3	3	3	3	3	-	-	-	-
13	*Nitzschia*	-	3	3	3	3	3	-	-	-	-
14	*Oscillatoria*	-	4	4	4	4	4	-	-	-	-
15	*Phacus*	-	2	2	2	2	2	-	-	-	-
16	*Pandorina*	-	-	-	-	-	-	1	1	1	-
17	*Phormidium*	-	1	1	1	1	1	-	-	-	-
18	*Scenedesmus*	-	4	4	4	4	4	4	4	4	-
19	*Stigesclonium*	-	2	2	2	2	2	-	-	-	-
20	*Svnedra*	-	2	2	2	2	2	2	2	2	-
	Total	2	40	41	41	41	37	14	14	13	3

Very light organic pollution has been observed at the sampling stations SS_0 and SS_9. Similarly, the sampling stations SS_6, SS_7 and SS_8 are facing in between very light organic pollution and organic pollutional problem. High organic pollution are occurred at the sampling stations from SS_1 to SS_5 due to receive of effluents and sewage water from the various sources.

8.3.5 Algal Species Index

Considering to the algal species in the Tunia river, the pollution index of the Tunia river at the various sampling stations are tabulated in the Table 8.12 for ascertaining the pollutional status of the river.

Table 8.12 : Pollution tolerant species of algae at different sampling stations of the Tunia river

Sl. No.	Algal genera	Sampling Stations									
		SS_0	SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_7	SS_8	SS_9
1.	*Ankistrodesmus falcatus*	3	3	3	3	3	3	3	3	3	3
2	*Chlorella vulgaris*	-	2	2	2	2	2	-	-	-	-
3	*Cyclotella meneghiniana*	-	2	2	2	2	2	2	2	2	-
4.	*Eugena vides*	-	-	-	6	6	6	-	-	-	-
5	*Gomphonema parvulum*	-	1	1	1	1	1	-	-	-	-
6.	*Navicula cryptocephla*	-	1	1	1	1	1	1	1	1	-
7	*Nitzschia palea*	-	5	5	5	5	5	-	-	-	-
8	*Oscillatoria tenuis*	-	4	4	4	4	4	-	-	-	-
9	*Oscillatoria chlorina*	-	2	2	2	2	2	-	-	-	-
10.	*Oscillatoria limisa*	-	4	4	4	4	4	-	-	-	-
11	*Oscillatoria princeps*	-	1	1	-	-	-	-	-	-	-
12	*Scenedesmus quadricauda*	-	4	4	4	4	4	-	-	-	-
13	*Stigeoclonium tenue*	-	3	3	3	3	3	-	-	-	-
14	*Synedra ulna*	-	3	3	3	3	3	3	3	3	-
	Total	3	35	35	40	40	40	9	9	8	3

According to the Palmer pollution index scale, the sampling stations SS_6, SS_7, SS_8, SS_9 and SS_0 are under very light organic pollution and high organic pollution has been observed at the sampling stations from SS_1 to SS_5.

8.3.6 Comparison of Genus and Species Index

The pollution index of the Tunia river at the various sampling stations are tabulated in the Table 8.13 under the algal genus and algal species index.

Table 8.13 : Pollutional status of the Tunia river under the algal genus and algal species index

Sl. No.	Sampling stations	Algal genus index		Algal species index	
		Index value	Status of pollution	Index value	Status of pollution
1.	SS_0	2	VLOP	3	VLOP
2	SS_1	40	HOP	35	HOP
3	SS_2	41	HOP	35	HOP
4	SS_3	41	HOP	40	HOP
5	SS_4	41	HOP	40	HOP
6	SS_5	37	HOP	40	HOP
7	SS_6	14	VLOP	8	VLOP
8	SS_7	14	VLOP	9	VLOP
9	SS_8	13	VLOP	8	VLOP
10	SS_9	3	VLOP	3	VLOP

VLOP = Very light organic pollution
OP = Organic pollution
HOP = High organic pollution

8.3.6.1 Very light organic pollution

The very light organic pollution has been observed at the sampling stations SS_0 SS_6, SS_7, SS_8, and SS_9, under both the index. The pollutional load is gradually diminishing due to self purification process of the river.

8.3.6.2 Organic pollution

The index value are slightly high at sampling stations SS_6, SS_7 and SS_8 as per algal genus index. The pollution status are in between the boundary level of organic pollution and very light organic pollution at these sampling stations as per genus index.

8.3.6.3 High organic pollution

The high organic pollution has been observed at the sampling stations from SS_1 to SS_5 under both the index calculation due to receive of effluents, sewage water and other organic matter from the various sources.

8.4 SUMMARY

The water quality index of the Tunia river has been calculated under the NSFWQI and Palmer's algal index.

The calculation of NSFWQI are performed for the period such as monsoon, postmonsoon, winter and premonsoon, respectively in a year and consequently, to ascertain the water quality of the Tunia river. A comparative index analysis for the aforesaid period also indicate the exact status of pollutional level in the Tunia river.

Similarly, the pollution index has been found by the Palmer's both algal genus and algal species index. Both the index ascertains the quality of river water and consequently, the Tunia river is facing a pollutional problem in respect of the organic pollutional load from the various sources.

EFFECTS OF WATER

9.1 GENERAL

The flora and fauna of a river has been affected due to receive of effluents and sewage from the various sources. Similar incident is also happened in case of the Tunia river. The flora, fauna and river ecology are gradually affected in the Tunia river due to receive of effluents and sewage from the various industrial units and urban area respectively. The effect is more in the upstream of the river where it receive effluents and sewage from the various sources.

Eutrophication, algal bloom and overgrowth of water hyacinth are observed in the upstream area. Fish population and diversity are gradually depleting in the river system.

The self purification of the river is also affected for continuously receive of effluents and sewage. Therefore, the river is unable to revive the polluted water to the original water at the source before confluence with the Champamati river.

The physicochemical parameters of a river are deteriorated by effluents and sewage and then damage the flora and fauna along with the river eco-system.

9.2 EFFECTS ON PHYSICOCHEMICAL PARAMETERS

The effluents and sewage first deteriorates the physico-chemical parameters such as physical, organic, mineral, and other inorganic parameters in the river water. These are found at the water quality analysis. The water quality and water quality index are ascertained and the results indicate the pollution level in the water of Tunia river. Details has been already illustrated in the earlier topics.

9.3 EFFECTS OF EUTROPHICATION

The Tunia river is facing a environmental problem of eutrophication due to human activities. The whole river is under the eutrophication. The problem is serious in winter and premonsoon due to low flow, low level of water and optimum temperature along with abundant of nutrients in water of the river.

Actually, the rate of eutrophication strikes a balance between the production of aquatic lifes and its destruction by bacterial decomposition. But with large inputs of nutrients from human activities, bacterial decomposition cannot keep pace with productivity and sedimentation is accelerated whereby eutrophication is favoured.

Causes of Eutrophication

The various causes of eutrophication are:

1. Discharge of domestic and municipal waste water.
2. Discharge of effluents from the industrial units.
3. Bathing of human beings and animals.
4. Washing of clothes and utensils.
5. Excreation of human beings and animals.
6. Discharge of dead animals.
7. Discharge of burning residue from the crematoria.
8. Immersion of pooja idols.
9. Strom water from the urban area
10. Run-off from the agricultural field.

The plants grows in the river depend upon the presence of nutrient content in river water. The luxuriant growth of plant has been initiated by nitrogen and phosphorus compounds in water. The various plants occupies in the Tunia river are water hyacinth (Eichhornia crassipes), Lemna minor Linn, Pistia stratiotes Linn, Hymenachne amplexicaulis (R) Nees, Vallisneria spiralis Linn, Nymphaea albalinn, Nymphaea-rubra Roxb, Enhydra fluctans Lour, Ipomoea aquatica Forsk, Alocasia formicata (Roxb) Schott and various groups of algae in the eutrophication process. The various plants occupies at different sampling stations of the Tunia river are given below in the Table 9.1. The figure 9.1 also show the eutrophication in the Tunia river.

FIG. 9.1: Eutrophication in the Tunia river

The process of eutrophication and its relationship to nutrient inputs is complex. Phosphorus and nitrogen takes important part for eutrophication in the Tunia river. Phosphorus dominating plants grows from sampling station SS_0 to station SS_5 and nitrogen bearing plants species occupies from sampling station SS_5 to SS_9. Phosphorus and nitrogen compounds comes from domestic waste water, human excreta, and agricultural run-off which accelerates the eutrophication process in the river. This findings has already been observed by Schindler, (1971) for his previous study in respect of eutrophication of the aquatic plants.

Table 9.1 : Various plants at the sampling stations

Sl. No.	Sampling stations	Location	Plants
1.	SS_0	Dhaligaon	*Algae (Bacillariophyceae, Chlorophyceae and Cyanophyceae), Water hyacinth, Enhydra fluctans, Ipomoea formicata, Lemna minor, Pistia stratiotes and Nymphaea albalinn.*
2.	SS_1	NH-31-C Dhaligaon	*Algae (Cyanophyceae, Euglenophyceae Bacillariophyceae and Chlorophyceae)*
3.	SS_2	Kukurmari	*Algae (Cyanophyceae, Euglenophyceae, Bacillariophyceae and Chlorophyceae) and Water hyacinth*
4.	SS_3	New-Bongaigaon	*Algae (Cyanophyceae, Euglenophyceae, Bacillariophyceae, and Chlorophyceae) Water hyacinth and Enhydra fluctans*
5.	SS_4	Railway bridge, New-Bongagaon	*Algae (Cyanophyceae, Chlorophyceae, Bacillariophyceae and Euglenophyceae) Water hyacinth and Alocasia formicata*
6.	SS_5	Bongaigaon	*Algae (Cyanophycae, Chlorophyceae, Bacillariophyceae and Euglenophyceae), Enhydra fluctans and Ipomea aquatica*
7.	SS_6	NH-31 Biotamari	*Algae (Rhodophyceae, Cyanophyceae, Chlorophyceae and Bacillariophyceae) Enhydra fluctans, Ipomoea aquatica, Lemna minor and Pistia stratiotes*
8.	SS_7	Silibari	*Algae (Rhodophyceae, Chlorophyceae, Bacillariophyceae and Chyanophyceae) Lemna minor, Pistia stratiotes, Hymenachne amplexicaulis, Nymphaea albalinn, Ipomoea aquatica and Vallisneria spiralis*
9.	SS_8	Champamukh	*Algae (Chlorophyceae, Bacillariophyceae and Cyanophyceae), Ipomoea aquatica, Lemna minor, Pistia stratiotes, Hymenachne amplexicaulis, Vallisneria spiralis and Nymphaea or balinn*
10	SS_9	Champamukh	*Algae (Chlorophyceae, Bacillariophyceae and Cyanophyceae), Lemna minor, Pistia stratiotes, and Hymenachne amplexicaulis*

Algae occupies whole the river about 5 groups of species. Actually, the growth of algae in a water body is proportional to the quantity of nutrients in the water body. Algal bloom has been occurred above 0.3 mg/l of inorganic nitrogen and 0.01 mg/l of phosphorus in the water system [91]. The Tunia river always contain the above limits for both the element in the river water. The heavy growth of water hyacinth blocks the flow of Tunia river and depleting the dissolved oxygen in water.

Seven and Walter has defined the eutrophication as the state of a water body which is manifested by an intense proliferation of algae and other higher aquatic plants and their accumulation in the water body in excessive quantities resulted as bloom due to nutrient enrichment of water. The organization for Economic Cooperation and Development (OECD) has also defined that the eutrophication quantitatively in terms of enrichment of total phosphates content in water. Both definitions has been followed by the Tunia river eutrophication process.

Eutrophication reduces the species diversity of flora and fauna but favours for harboures of diseases producing vectors in the Tunia river water systems. Fish species are gradually decreasing by lowering dissolved oxygen level due to eutrophication in river water.

9.4 EFFECTS ON ALGAE

Algal bloom has been happened in the Tunia river due to its favourable condition for the growth of algal bloom. This occurred in premonsoon and summer season where temperature and sunlight are optimum for their growth. Higher population and species diversity are occurred from the sampling station (SS_1) to the station (SS_5).

The following favourable factors are responsible for algal bloom formation in the Tunia river.

1. High temperature and optimum light.
2. High organic matters
3. Fluctuation of low and high DO
4. High pH above 7.0.
5. Concentration of nitrate in excess of 0.3 mg/l.
6. High inorganic nutrients of phosphate and nitrogen compounds.
7. Low water depth.
8. Reduces flow of water with seasons.

The nutritional requirements of the algae differ markedly from one group to another group and depend upon physicochemical factors for the different groups of algae growth in the aquatic system. Regarding to this cause, 5 groups of algae are observed in the Tunia river. These are Cyanophyceae, Chlorophyceae, Bacillariophyceae, Euglenophyceae and Rhodophyceae and they occupies different location as per depend upon the physicochemical condition in the river.

Cyanophyceae : This group has dominated at the station (SS_1) which are receiving BRPL effluent by the Tunia river before this station. Cyanophyceae are more tolerable than other groups of algae against the oil pollution. Cyanophyceae are gradually decreasing from the sampling station (SS_1) to the sampling station (SS_5). About 39.53% at SS_1, 38.69% at SS_2, 28.57% at SS_3, 28.3% at SS_4 and 17% at SS_5 are present in the said sampling stations. This group are represented by highest number of species as well as the largest number of individual. Cyanophyceae is also known as blue green algae.

The organic matter plays a deciding role in causing blooms of Cyanophyceae in the tropical water system. When oxidisable organic matter in low then the growth of Cyanophyceae is optimum and higher oxidisable organic matter retards their growth. Due to this cause, Cyanophyceae is maximum at station (SS_1) and gradually decreases to the downstreams of the river. Phosphate and nitrate are also less at sampling station SS_1 and SS_2 which favours the growth of cyanophyceae than other groups of algae.

Similarly, low pH and DO at sampling stations SS_1 and SS_2 which initiate favourable growth of certain species of Cyanophyceae. When pH is about 7 and low DO then also stimulate the growth of Cyanophyceae.

The bloom formation of Cyanophyceae is more during the monsoon period where temperature is high and optimum levels of sunshine in the Tunia river water environment.

Chlorophyceae : The Chlorophyceae group is also known as green algae. This group is completely dominated from the sampling station SS_3 to station SS_5 where sewage and domestic waste water is mixed with the Tunia river water and reduces oil and grease content in the river water. Chlorophyceae occupies 32.6% at SS_3, 33.9% at SS_4 and 37.77% at SS_5. Gradual decreasing has been observed from station SS_5 to the sampling station SS_9.

The high average concentrations of oxidisable organic matter and nitrogeneous organic compounds highly influences the growth of Chlorophyceae. High phosphates and oxidisable organic matter are also favours the growth of Chlorophyceae. Similarly high pH and low DO also initiate to stimulate the growth of Chlorophyceae. The relative high temperature of sewage also initiates the growth of Chlorophyceae.

The algal bloom of Chlorsphyceae has been occurred during the season of premonsoon and summer where favourable conditions are optimum.

Bacillariophyceae : Bacillariophyceae occupies in whole stretch of the Tunia river as per depend on high or low pollution load. Bacillariophyceae has more grown in fresh water bodies or slightly polluted water system. Species diversity has been reduced at high pollution load. Bacillariophyceae has occupied about 60.90% of the total algal species at the sampling station SS_0. After receiving of BRPL effluent, the species are gradually varying to the sampling station SS_3. About 23.25% at SS_1, 22.72% at SS_2, and 24.48% at SS_3 are observed in the said sampling stations. The species increases at station SS_4 to station SS_9 due to decreasing trend of pollution load i.e. 24.53% at SS_4, 31.11% at SS_5, 54% at SS_6, 46.52% at SS_7 , 50% at SS_8 and 51.72% at SS_9. Regarding this, Bacillariophyceae has grown favourably in fresh water or slightly polluted water bodies.

The favourable grown of Bacillariophyceae has been influenced by high DO and lower concentration of BOD, COD, phosphate and oil and grease. Due to this cause, large numbers of species has been observed at the downstream area where pollution load gradually diminishing due to its self purification process of the river.

The growth of Bacillariophyceae are luxuriant in the late winter season and peak in premonsoon period.

Euglenophyceae : There are 7 species of Euglenophyceae are found in the Tunia river. Euglenophyceae respond quickly to ecological changes when water are polluted and therefore many occurred during summer season. As a results, the presence of Euglenophyceae indicates the pollutional status in the river water. The species of Euglenophyceae are present 11.63% at SS_1, 13.64% at SS_2, 14.28% at SS_3, 13.20% at SS_4 and 13.3% at SS_5 of the total algal species of the respective sampling station. These stations contains high organic matter, low level of DO and slightly higher temperature. Higher phosphates and lower concentration of dissolved oxygen favours the growth of Euglenophyceae. All the above stations provides favourable physicochemical conditions for the growth of Euglenophyceae.

The Euglensphyceae are absent from the station SS_6 to station SS_9 due to high DO and low temperature and presence of other chemical parameters.

The bloom formation of Euglenophyceae is generally occurred in the premonsoon season.

Rhodophyceae : There is only one species of Rhodophyceae are found at the sampling station SS_6 and SS_7. Rhodophyceae are totally absent from SS_1 to SS_5 due to presence of high oil and grease in the water. The species of Rhodophyceae are grown at natural water or slightly polluted water bodies.

The bloom formation generally occurs in last winter and premonsoon seasons.

9.5 EFFECTS ON WATER HYACINTH

Water hyacinth (Eichhornia crassipes) flourish abundantly in polluted water bodies and changes the water quality by increasing the nutrient levels and by decreasing the dissolved oxygen in the water. The polluted waters provides a high level of micro nutrients which become favourble for the growth of water hyncinth in the Tunia river. The water hyncinth occupies whole area of the Tunia river from the sampling station SS_2, Kukurmari to sampling station SS_3, New Bongaigaon. The human excreta are directly falled into the river from about 100 katcha latrine which are situated at New Bongaigaon on the bank of the river. As a result, human excreta accelerates the growth of water hyacinth tremendously in the river. The Figure 9.2 shows the over growth of water hyacinth in the Tunia river.

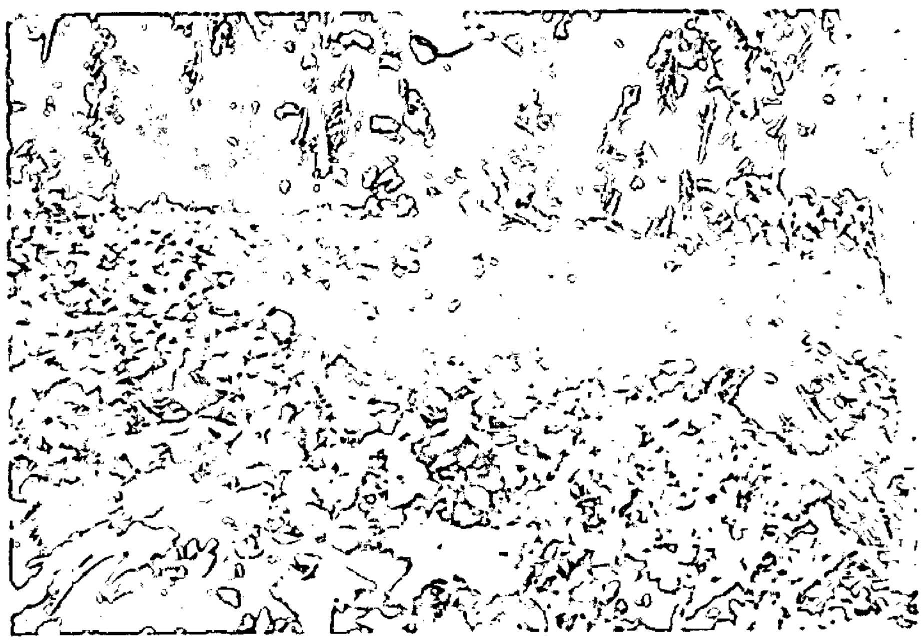

FIG. 9.2: Over growth of water hyacinth in the Tunia river

The growth of the water hyacinth takes place by germination of seeds and also by vegetative multiplication of stolons. The growth is so fast and a single plant can multiply to 1200 – 1250 in number in a 4 months period. The heavy growth creates the environmental problems such as hindrance to the flow of river, movement of fish and other aquatic fauna and adverse affect on the other aquatic plants in the Tunia river.

The wild growth has been occurred between in February and May due to low flow, low depth of water, high nutrient and favourable temperature. The physicochemical and biological characteristics of water hyacinth are:

Physicochemical:

The water hyacinth indicates the pollutional status of a water bodies due to their presence of excess growth in the water. It has the ability to adapt and grow tremendously in polluted water systems. Fresh and clean water does not support excess growth of water hyacinth. Water hyacinth has the ability to adapt and grow excessively in polluted water system.

The physico chemical characteristics of the Tunia river water get highly changed in the presence of water hyacinth from Kukurmari to New Bongaigaon area. The floating mats of water hyacinth provides obnoxious smell and deep colour to the water and deplete its dissolved oxygen and hence reduce the natural ability to absorbs organic pollution. As a result, it creates septic nature and odorous condition.

The heavy growth of water hyacinth reduces temperature in water and increases pH, alkalinity and hardness of water. The water hyacinth also depletes the dissolved oxygen in water due to obstruction of contact of air with water by heavy mat formation of the water hyacinth.

The chloride and phosphate accelerate for the growth of water hyacinth in the Tunia river which come to the river water from the sewage and human excreta by discharging about 100 katcha latrine directly. The fluoride of 1 – 1.2 mg/l in river water also favour excessive growth of water hyacinth.

Biological

The biological characteristics of excessive growth of water hyacinth favour the harboured habitat for mosquitoes, dragon flies, aquatic beetles, water mites, snails and other disease producing vectors. It hampers the fish growth and other aquatic lifes due to depletion of dissolved oxygen by excessive mat formation of water hyacinth.

The loss of water by evapotranspiration through the water hyacinth are 3 to 8 folds higher than the loss of water by evaporation from the open surface of water bodies. Floting mats of hyacinth curtail the penetration of sunlight which adversely affect on the growth of submerged hydrophytes, phytoplanktons and other aquatic plants.

High evapotranspiration, obstruction of water flow, curtail of sunlight, depletion of dissolved oxygen and heavy mat formation reduces the species diversity of flora and fauna in the Tunia river and ultimately create partial anaerobic water environment which release odorous smell. Besides, the monospecific mat which extends from the bottom to the surface of water blocks the availability of nutrient and micronutrients which are necessary for the survival of other aquatic flora and fauna.

9.6 EFFECTS ON FISH

The fish has been gradually affected due to increasing pollutional load in the Tunia river. Dissolved oxygen is more essential for fish and other aquatic lifes but it gradually diminishing upto 3 mg/l or less owing to increasing BOD, COD and other pollutional load. Therefore, fishes are not survive during this limit. Besides, continuing receives of domestic sewage and industrial waste water, high turbidity and eutrophication initiates adverse affect the movement of fish in the river water. Oil and grease is also affecting their movement and obstructing to take oxygen from the air during the time of breathing. The phenolic compounds tends to increase the toxicity affect on fish and other aquatic lifes, ultimately which assist to gradual depleting in the river.

The following parameters are tabulated in the Table 9.2 for responsible of their affects on fish.

Table 9.2 : Affect on fish by parameters at various seasons

Sl. No.	Parameters	Monsoon	Post-monsoon	Winter	Pre-monsoon
1.	Oil and grease	A	A	A	A
2.	Phenolic compounds	A	A	A	A
3.	Dissolved oxygen	LA	LA	A	A
4.	BOD & COD	LA	LA	A	A

LA = Less affects, A = Affects

Fishes are ecological indicator of indicating pollution nature in the river. Emigration of fish like Catla, Labeorohita, Labeobata, Notopterus etc. indicates industrial pollution in the river. Earlier, the species such as Catla, Labeorohita and Labeo bata are available in the Tunia river before setting up the BRPL. Due to diminishing such species, it indicate the water of the Tunia river is suffering from the industrial pollution.

Fishes are best indicator of river health because they are at the top of the food chain. Fish have home ranges and territories within which they move and outside which they rarely go. However, they will go outside to get away from pollutants that they can detect and perhaps be distress by. Many pollutants which are not detected and fish are suffering as they do from a very rapid pollution. Fish are usually avoid severe organic pollution and they are repelled by low oxygen level at high temperature. Where carbondioxide rises due to decarying organic matter, fish appears to need more oxygen and are less sensitive to ammonium poisoning.

The Indian standard tolerance limits for inland surface waters for fish culture is given in the Table 9.3 as per the IS – 2296, 1974.

Table 9.3 : Tolerance limits of parameters in the surface water for fish (IS – 2296, 1974)

Sl. No.	Parameters	Tolerance limits
1.	PH	6.0 – 9.0
2.	EC at 25^0C (mhos)	1000×10^{-6} (max)
3.	Free CO_2 (mg/l)	6 (max)
4.	Free NH_3 (as N, mg/l)	1.2 (max)
5.	DO (mg/l)	40% saturation value (min) or 3.0 mg/l, whichever is higher
6.	Oil and grease (mg/l)	0.1 (max.)

Phenol and its compounds are the common constituents in the effluents of the BRPL. This phenol and its compounds are toxic to fish at lower concentration and adversely affect the physiology. The concentration of phenol and its compounds in the Tunia river is 0.1 mg/l or more. Therefore, it affect the fish through inflammation of liver, enlargement and rupturing of hepatocytes and their nuclei, spilitting, liquifaction, hypertrophy, necrosis and vacuolation of the tissue and degeneration of blood vessels. As a result, the fish mortaility rate is increased and depleting the fish diversity.

The oil and grease is more high in the Tunia river water than the prescribed limits as specified by IS-2296, 1974. This chemicals inhibit the breathing of fish and hinder to movement of fish in water. It also affect the gills of a fish and hence unable to take oxygen from the air during the breathing. Consequently, fishes are gradually unable to survive in the water of the Tunia river.

The most important parameter is dissolved oxygen for fish culture. Due to continuous receiving of domestic waste water, effluents and other wastes, the dissolved oxygen is gradually depleting upto 3 mg / lit or less. Therefore, fish are gradually diminishing from the river.

The above findings had already been observed by Pandey et al., (2000), David (1956), Thomson (1928) and Das (1998) for their respective studies of pollution on fish and other aquatic lifes. Fish and other aquatic lifes are depleted gradually and ultimately the river is free from the fish and other higher aquatic lifes from the river system.

9.7 EFFECTS ON BACTERIOLOGICAL PARAMETERS

The bacteriological parameters such as total coliform and faecal coliform are high in water of the Tunia river. This is happened due to discharge of effluents and sewage water into the river. Basically, sewage water are discharged without treatment. Besides, human excreta are discharging directly to the river through 100 of katcha latrine in the New Bongaigaon area. Consequently, total coliform and faecal coliform are increased, ultimately which indicate the presence of pathogen in water of the Tunia river. Pathogens are bacteria, viruses, protozoa and helminths which initiates to create water brone diseases.

The faecal coliform is a good indicator for indicating the pathogen. The faecal coliform satisfy the following criteria, as a good indicator of pathogen.

1. be applicable to all types of water
2. always be present when pathogens are present.
3. always be absent when pathogens are absent.
4. lend itself to routine quantitative testing procedures without interference from or confusion of results because of extraneous organisms, and
5. for the safety of laboratory personnel, not be a pathogen itself.

Faecal coliform are native to the intestinal tract of humans and meeting the above criteria. The main group of faecal coliform are Escherichia coliform (E. Coli) and Faecal Streptococi (F.S. Coli). Faecal Coliform are generally non pathogenic and indicate the presence of pathogen.

Total coliform group are both faecal and non faecal nature. This group are also used as indicator for the sanitary quality of drinking water in USA.

Due to high content of faecal and total coliform, it indicate that pathogen are present in the water of the Tunia river. People in the catchment area of the downstream are generally suffered from amebiasis disease such as amebic dysentery, amebic enteritis and amebic colitis after flood hazards. Therefore, it indicate that the presence of Entamoeba histolytica of protozoa pathrogen in the river water. As a result, amebic dysentery are the major disease and people are generally suffering from this disease in the downstream area of the river.

9.8 EFFECTS ON SELF PURIFICATION

The self purification mechanisms of the Tunia river include physical, chemical and biological processes. The speed and completeness of this process depend on many variables that are system specific [30]. Hydraulic characteristics such as volume, rate and turbulence of flow, physical characteristics of bottom and bank material, variations in sunlight and temperature, as well as the chemical nature of the natural water are all system variables that have an influence on the natural purification process of the river. Basically, the physical, chemical and biological processes that serve to purify natural water systems also work in engineered systems.

Physical Processes

The physical processes involved in self purification process are dilution, sedimentation and resuspension, filtration, gas transfer and heat transfer.

. Natural water has been mixed with the Tunia river water by the small streams which come from the hilly area in Nakati reserved forest and Bhairab reserved forest. As a result, the pollutional load is gradually diminishing in the downstream area of the river.

Sedimentation initiates to removing suspended particles from the river water. Resuspension of solids is done during the time of summer. Therefore, increased turbulence may resuspend solids formerly deposited along normally quiescent areas of a stream and carry the matters for considerable distance of downstream. Oil sludge are redeposited to the longer distance in the river.

The transfer of gases into and out of water is an important part of the natural purification process. The replenishment of oxygen to bacterial degradation is accomplished by the transfer of oxygen from the air into the water. Conversely, gases evolved in the water by chemical and biological processes are transferred from the water to the air. A large area of the reserved forest in the catchment area of the Tunia river influences easy transfer of gases from water to air or vice-versa.

Temperature of river water influences the self purification process of the river. The average temperature range is 19 – 27.5^{0}C in water of the Tunia river which helps to increase the rate of self purification.

Chemical Processes

The river water contain many dissolved minerals and gases that interact chemically with one another in complex and varied ways. Oxidation and reduction, dissolution and precipitation and other chemical conversions aid purification of the river water.

Most of the oxidation and reduction are biochemically mediated. Dissolution and precipitation initiate the metabolic and reproductive activities of the micro-organisms which degrade and stabilize organic wastes. Precipitation also removes the undesirable matter from the water and settle at the bottom of the river. Other chemical conversion take place to change the pollutant to soluble form and ultimately usable by various aquatic plant and organisms.

Bio-Chemical Processes

The biochemical process is a very complex form. The process which convert the biodegrable organics and other nutrients into food by the micro organisms for subsistence, growth and reproduction is called metabolism.

The metabolism are extremely complicated and are not yet completely understood. There are probably 3 process, catabolism, anabolism and endogenous catabolism. The catabolism provides the energy for the synthesis of new cells, as well as for the maintenance of other cell functions. When an external food source is interrupted, the organisms will use stored for maintenance energy in a process is called endogenous catabolism. The anabolism provides the material necessary for the cell growth.

Enzymes plays a major role in the biochemical reaction and enzymes lower the activation energy necessary to initiate the reactions. The micro-organisms in the natural purification process are bacteria, protozoa, notifers, crustacea and algae. Each type of micro-organisms has its own metabolic pathway from specific reactants to specific end products which is unpolluted nature and reuse by other aquatic lifes.

Briefly speaking that the natural self purification of a water system is a complex process that often involves physical, chemical and biological processes working simultaneously. Chemical and biochemical reactions are conversion processes rather than removal processes. The products of the chemical and biochemical reactions remain in the water until physical processes remove them from suspension by sedimentation or by transfer to the atmosphere.

The water quality of the Tunia river is not recover to the original state by the self purification process. The water quality is class A water at the source and class D water before confluence of Tunia river with the Champamati river. These causes are limited length of the river, minimum flow, presence of oil and grease, phenolic compounds and other high pollutional load with compare to the assimilative capacity of the river. Therefore, the natural self purification capacity has been disturbed in the Tunia river by receiving of effluents and sewage water inspite of the favourable natural condition for self purification process.

9.9 RIVER ECOLOGY OF TUNIA RIVER

The graph of dissolved oxygen Vs time or distance of a river is known as oxygen sag curve [94]. The dissolved oxygen and temperature are measured on 11.01.2006 in a same day at all the sampling stations of the river. According to the characteristics of the oxygen sag curve, the self purification process of the Tunia river with respect to the dissolved oxygen and aquatic plants (autotrops) may be described under the ecological model usually involves dividing the Tunia river into 4 zones as:

1. Zone of degradation
2. Zone of active decomposition
3. Zone of recovery
4. Zone of clean water.

1. Zone of Degradation

The area from the sampling station SS_1 to SS_5 is under the zone of pollution. All industrial effluents and sewage water are confluenced in this area of about 4.50 km stretch of the river. The dissolved oxygen is gradually decreasing within these stations due to abundant supply of biodegradable organic matter. This zone is characterized by water becoming dark and turbid with formation of sludge deposits at the bottom of the river. Generally, oily sludge are found near the sampling station SS_1 and SS_2. The dissolved oxygen is reduced to about 35.10% of the saturation value. The reoxygenation occurs but it is very slower than the deoxygenation. It is also observed that there is no any fish in this area. Some aquatic plants are found which are more resistance to the organic pollution and mentioned in the Table 9.4.

Table 9.4 : Aquatic plants at the various zones of the river

Sl. No.	Zone	Physical characteristics	Chemical characteristic	Biological characteristics
1.	Degradation Zone-2 In Fig. 9.3	The water is turbid, deposits sludges and floating debris	49.17 to 35.10% saturation of DO	Fish are absent, Euglenophyceae, *Cyanophyceae, water hyacinth, Enhydra fluctons* and pollution resistance plants are predominate. Water fungi are typically white, olive green, putty gray and rusty brown.
2.	Active decomposition (Zone-3) in Fig. 9.3	Water is grayish and darker than in degradation zone	35.10 to 44.46% saturation of DO	*Chlorophyceae, Bacillariophyceae, Rhodophyceae,* water hyacinth, various grass and pollution resistance aquatic plants are grown. Bacteria flora flourish, protozoa follow course of aerobic bacteria and fungi also follow a similar course. Fish are not found.
3.	Recovery (Zone-4) in Fig. 9.3	Water is clear	44.40 to 74.62% saturation of DO	*Bcillariophyceae, Chlorophyceae* and Cyanophyceae are present with other small aquatic plants. *Protozoa, rotifers* and *crustacea* appear. *Fungi* are present to a limited degree. Bottom organisms include *tubifex, mussels, snails and insect larvae.*
4.	Clean water (Zone-1 & 5) in Fig. 9.3	Natural stream conditions are restored	74.62 to 80.37% saturation of DO	*Bacillariophyceae and Chlorophyceae* are predominated along with small aquatic plants. Fish are present with other aquatic fauna.

The food supply is a primary factor for predominance of organisms. bacteria, protozoa and molds predominates near the discharge point. The bacteria decomposes the organic wastes into nutrient materials such as nitrates, phosphates and carbon-di-oxide for food in favour of protozoa, ciliates, rotifers and crustacea. The bacteria populations flourish until dissolved oxygen and the food supply is exhausted.

The sampling station SS_5 represent the maximum impact on the dissolved oxygen due to receive of high amount of sewage water from the Bongaigaon town. The critical deficit of dissolved oxygen is 6.096 mg/l and the station is called the critical deficit point of dissolved oxygen of the Tunia river.

2. Zone of Active Decomposition

This area covers the sampling station from SS_5 to SS_6 with a length of about 19 km in the Tunia river. The dissolved oxygen ranges from 35.10 to 44.40% of the saturation value. Dissolved oxygen is gradually increased by the reaeration. Therefore, the rate of reaeration overcome the rate of deoxygenation.

Water is grayish and darker than the degradation zone. Methan, and hydrogen sulphide may be released into the air. The abundant supply of nutrient materials made available by the bacterial decomposition of organic matter brings about still further changes. Algae begin a rapid increase in this area.

3. Zone of Recovery

The river area covers from the sampling station SS_6, NH-31 bridge, Biotamari to SS_7, Silibari at a distance of about 11 km in the Tunia river. Dissolved oxygen ranges from 44.40 to 74.62% of the saturation value. Therefore, the dissolved oxygen is gradually increased by the reaeration due to peak algal growth and favourable hilly natural environment.

The river tries to recover from its degraded condition to its earlier appearance. Water becomes clear owing to algal activity while fungi decreases. The BOD falls down against increasing the dissolved oxygen. Protozoa, rotifers, crustaceas and other aquatic plants are more active in the zone. Bottom organisms like tubifex, mussels etc. are also present and the organic matter has been mineralized to form nitrates, sulphate, phosphate and carbonates.

4. Zone of Clean Water

This river area covers from the sampling station SS_7 , Silibari to SS_8 Champamukh. Nutrient load and BOD decline and DO level return to their natural levels. Algae and bacteria populations return to their clean water status. The clean water invertebrate and vertebrate fauna again populate the stream. Fish like Ophiocephalus punctatus, Amphibius cuchia, Putius putius etc. are observed due to 74.62 – 80.37% of saturation value of dissolved oxygen in the water.

The polluted river ecology of the Tunia river is shown in the Figure 9.3.

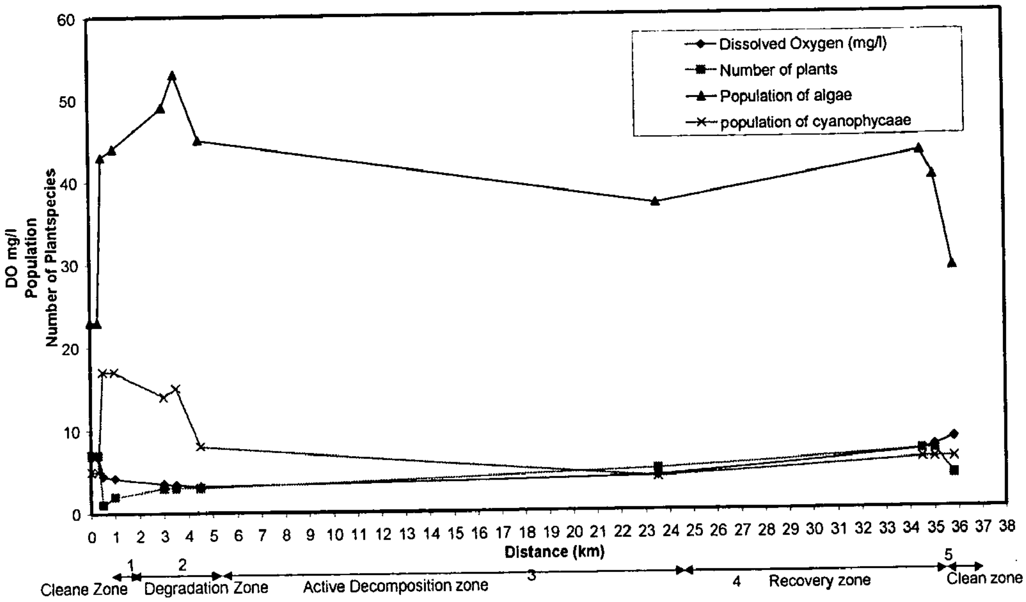

FIG 9.3: Changes in population, nos. of plants and DO by receiving of effluent and sewage in the Tunia river

The initial oxygen deficit are occurred by 2.496 mg/l due to natural biological activities of the river. The critical oxygen deficit 6.096 mg/l at sampling station, SS_5 is a critical condition for sustaining the aquatic lifes. Due to high critical oxygen deficit, the polluted water is not totally revived to their original state at source by the self purification process. Therefore, the river water quality attain class D as per the CPCB classification before confluence with the Champamati river.

9.10 SUMMARY

The effluents and sewage of various sources affect the flora and fauna in the river ecosystem. High nutrient initiate to growth of eutrophication along with algal bloom and overgrowth of water hyacinth. The polluted water also affect the fish along with other aquatic fauna.

The adverse affects of urbanization and industrialization first affect the physico-chemical parameters in the river water and subsequently, affect the whole river eco-system. Consequently, the natural self purification process of the Tunia river are gradually less efficacious.

CONCLUSION

10.1 CONCLUSION

The effluents and sewage water always affect the neighbouring water resources in an urban area. Similar results have also been observed in case of the Tunia river. The effluents and sewage water from various sources affected the water quality alongwith the flora and fauna in the Tunia river eco-system. Therefore, the following important conclusions are summarized after studying the Tunia river in respect of the current dissertation work.

1. The Tunia river is facing moderate pllutional problem as per the percentage saturation of dissolved oxygen classification. The water quality before confluence with the Champamati river is under the category of no or slight pollutional status. This indicates that the river is polluted due to effluents and sewage it receives from the various sources.

2. The biochemical oxygen demand classification also reveals that the water quality of the Tunia river is of bad category due to high content of organic matters in the water. The water quality before confluence with the Champamati river is under the category of doubtful pollutional status. Therefore, it indicates that the river is under the organic pollutional problem and the river is unable to revive to its natural status by the self purification process in the river.

3. The water quality of the Tunia river is of class E category as per the CPCB and ISI classifications. This indicates that the water can be used for irrigation, industrial cooling and controlled waste disposal. The water before confluence with the Champamati river is under the category of class D water which can be used for propagation of wild life and fisheries. Therefore, the water before confluence with the Champamati river is not fully recoverable to its original states by its self purification process.

4. The water quality index such as NSFWQI and Palmer's algal index are used to ascertain the water quality of the Tunia river. The NSFWQI indicates the water quality is in between bad and medium ranges. The water quality is more deteriorated in winter and premonsoon periods.

5. Palmer's algal genus index and Palmer's algal species index reveal that the Tunia river is suffering from the high organic pollutional problem due to effluents and sewage water it receives from the various sources. It may be mentioned that high organic pollution in the reach between Dhaligaon and New Bongaigaon had already been observed by Adhikary, (1997) [3].

6. The water contains very high total coliform and faecal coliform which indicate the presence of pathogens in the river water, and consequently, it initiates water brone diseases in the downstream area of the river.

7. The flora of the Tunia river has been affected due to presence of abundant nutrient matter in the river water. The algal bloom and willy growth of other aquatic plants are observed in the whole stretch of the river. Similarly, over growth of water hyacinth at the Kukurmari area blocks the river flow.

Therefore, the river is under the hazards of eutrophication environmental problem.

8. The fauna are also affected due to effluent and sewage water it receives from the various sources. Fish are gradually disappeared from the river.

In view of the above, the water quality of the Tunia river is gradually deteriorated due to industrialization and urbanization in the Bongaigaon town and subsequently, it affects the flora and fauna of the Tunia river water system.

The Tunia river is not only a local water resources of Bongaigaon but it is also a state water resources in the state. The adverse effect on flora, fauna, self purification process, physico chemical, bacteriological and other effects can be relieved by implementing proper pollution control plans and management against the polluting sources.

Other human activities which deteriorates the quality of river water can also be minimized as far as possible for the greater interest of flora and fauna of the river eco-system. Public participation and public awareness programmes should be initiated for the greater interest of water resources of the Tunia river for better prospect of human life.

10.2 LIMITATIONS

The limitations of the present study are as follows:

1. Only grab samples were collected.
2. The time lag in the analysis for few parameters because of distances between the sampling stations and laboratory are unavoidable.

3. Approach roads are not adequate for collecting samples from the sampling stations.
4. Frequent rainfall may alter the concentration of parameters during collection of samples from the sampling stations.
5. The flow of river water is less in premonsoon.
6. The time constraint for carrying out such work restrain detailed study.

10.3 SCOPE OF FUTURE WORK

The scope of the future study may be as follows:

1. The affect on macro invertebrate and micro invertebrates may be studied due to continuous receiving of effluents and sewage.
2. The affect on fauna of the Bhairab and Nakati reserved forest may be studied where animals are drinking and swimming in the water of the Tunia river.
3. The affect of pollution on ground water in the neighbouring area by the Tunia river water due to increasing pollutional load.
4. The affect of pollution on the surrounding agricultural land by the Tunia river flood waters during the time of flood season.
5. The behaviour of river system may be studied more logically if sampling is done for a long period and water quality status and water quality index charts are prepared.

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