WATER QUALITY MANAGEMENT OF GODAVARI RIVER IN NASIK CITY

A DISSERTATION

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

of

MASTER OF TECHNOLOGY

in

CONSERVATION OF RIVERS AND LAKES

By

CHAVAN AJAY DAULAT

ALTERNATE HYDRO ENERGY CENTRE
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE - 247 667 (INDIA)

JUNE, 2008

CANDIDATE'S DECLARATION

I hereby declare that the work presented in this Dissertation report entitled **"WATER QUALITY MANAGEMENT OF GODAVARI RIVER IN NASIK CITY"** 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 between July 2007 to June 2008 under the guidance of **Dr. Renu Bhargava, Professor**, Civil Engineering Department, Indian Institute of Technology, Roorkee and **Dr. M. P. Sharma, Associate Professor,** Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee.

The matter contained herein has not been submitted by me for the award of any other degree or diploma elsewhere.

Date: 30th June, 2008

Place: Roorkee

CHAVAN AJAY DAULAT

M. Tech (CRL)

AHEC, IIT Roorkee

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

(Dr. Renu Bhargava)
Professor,
Civil Engineering Department,
Indian Institute of Technology,
Roorkee – 247 667 (Uttarakhand)
INDIA

(Dr. M.P. Sharma)
Associate Professor,
Alternate Hydro Energy Centre,
Indian Institute of Technology,
Roorkee – 247 667 (Uttarakhand)
INDIA

ACKNOWLEDGEMENT

First and foremost, I would like to thank **GOD** for giving me this opportunity to be here and to complete my post graduation degree from this reputed institute.

I heartily like to acknowledge my sincere gratitude and indebtedness to my guides, **Dr. Renu Bhargava**, Professor, Civil Engineering Department, Indian Institute of Technology, Roorkee and **Dr. M.P. Sharma**, Associate Professor, Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee for their precious guidance and kind information, continuous help and the affectionate treatment and constant help throughout the course of this dissertation work. Their useful suggestions and meticulous scrutiny of this work are gratefully acknowledged.

I wish to express my profound gratitude to **Shri Arun Kumar**, Head, Alternate Hydro Energy Centre, **Dr. R.P. Saini**, Associate Professor and Course Coordinator (Conservation of Rivers and Lakes), Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee for providing all the facilities at the Centre, which have made it possible for me to complete this dissertation report. The cooperation they gave is greatly appreciated.

I would also like to thank **Shri P.P. Nandusekar**, Principle Scientific Officer and **Shri P. K. Mirashe,** Regional Officer, Maharashtra Pollution Control Board for his help, affectionate treatment and contributing technical ideas during the time of data collection.

I am eternally indebted to my parents and family members for their love, constant support and encouragement.

Finally, I would like to thank all my friends at home and in Roorkee and the staffs of Alternate Hydro Energy Centre and Civil Engineering Department who have directly and indirectly helped me in successfully completing this dissertation work.

Date: 30th June 2008 **(AJAY D. CHAVAN)**

ABSTRACT

The Godavari River is a second largest river in India and originates from Trimbakeswar, Nasik Maharashtra and passes through the Nasik city. It adds an aesthetic value for the beautification of Nasik city. The study covers about 65 km stretch of river starting from Kushawart Trimbakeswar to Saikheda Village, from where the river enters the city. For convenience of study, a reference point is assumed as Origin of the river. The river water is used for washing clothes, bathing and other uses. Ten sampling stations were selected for collection of water sample from river Godavari. The collected water samples were analyzed in Environmental Laboratory of Maharashtra Pollution Control Board and Om Laboratories for various water quality parameters. The observed values of various water quality parameters were discussed and compared with the prevailing standards, corresponding to use of the water body. The analytical results have shown that the river is grossly polluted with high BOD. The DO decreases gradually as soon as the river enters the city. Moreover, the water body is highly polluted with faecal coliform, which indicates the discharge of untreated domestic sewage into it.

The water of the Godavari River collected at the various sampling stations from the different point sources has been analyzed for the physico-chemical parameters and bacteriological parameters such as total coliform and faecal coliform. The water quality has been evaluated as per standard methods. The comparison of the water quality of the river reflects the extent of pollution at respective sampling stations and different point sources which help to plan necessary measures to combat pollution of the river.

The NSFWQI online software has been used to evaluate the water quality of the Godavari River. The NSFWQI is mostly used in the USA and also applicable to the Indian water environment. The trends have indicated that in the study stretch of river, the vast variations in all the parameters were found perhaps due to the addition of various pollutants at various locations. Gangapur Dam is found as the second sampling station where river is almost pollution free and Tapowan or downstream of the Nasik is the eighth sampling station up to where it receives maximum pollution from the city.

Based on the results of water quality assessment of the River Godavari, it is observed that the overall water quality of the River Godavari is "bad" or "medium" as fact reflected at all the sampling locations. The NSFWQI observed between 26 to 50 and 51 to 70 indicates that the water quality of the Godavari River is between bad – medium range, further the results of the year 2003 and 2007 indicate the improvement in water quality at all locations because of the existing conservation measures being taken by the Nasik Municipal Corporation. Major stressor of pollution has been found as pollution due to sewage i.e. organic pollution with main contribution from faecal coliforms, BOD and reduced DO. The water quality maps prepared on the basis of NSFWQI have also indicated the same trend. These maps can be used to plan conservation measures for achieving the objectives. Existing conservations are three sewage treatment plants having capacity 78 MLD, 7.5 MLD and 22 MLD at Tapowan, Dasak and Takali respectively, solid waste treatment plant and bio- Medical waste treatment plant appear to be inadequate to improve the water quality due to substantial improved population.

A few conservation measures have also been suggested in order to restore the River Godavari back to its pristine state. There is no doubt that the River Godavari is a polluted river. However, if all the stakeholders join hands together and seriously act to conserve it, there is still a chance to restore it back to acceptable levels.

CONTENTS

NOTATIONS AND ABBREVIATIONS

Symbol / Abbreviation	Meaning / Explanation
Amm. N.	Ammonical Nitrogen
APHA	American Public Health Association
AWWA	American Water Works Assocation
BOD	Biological Oxygen Demand
CEQ	Council of Environmental Quality
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
DBU	Designated Best Use
DO	Dissolved Oxygen
DW	Discriptor Words
FC	Faecal Coliform
HOP	High Organic pollution
IV	Index Value
ISI	Indian Standard Institute
MICO	Motor Industries Company Limited
MPCB	Maharashtra Pollution Control Board
MSEB	Maharashtra State Electricity Board
MPN	Most Probable Number
NSFWQI	National Sanitation Foundation Water Quality Index
NMC	Nasik Municipal Corporation
NTU	Nephelometric Turbidity Unit
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
WPCF	Water Pollution Control Federation
WQI	Water Quality Index

LIST OF TABLES

LIST OF TABLES

LIST OF FIGURES

LIST OF GRAPHS

LIST OF MAPS

LIST OF PHOTOS

CHAPTER 1

INTRODUCTION

1.1 GENERAL

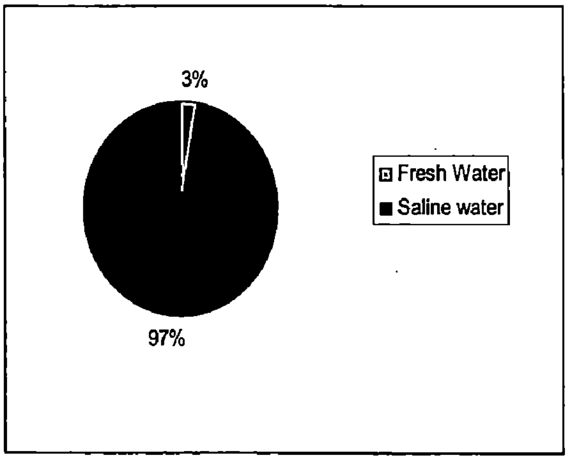
Water is colorless, tasteless, and odourless and is made up of only two elements, but it is a substance that no one can live without it and is, therefore, the basis for survival and growth not only of human beings but also all plants, animals and micro-organisms on the earth. All the known ancient civilizations existed along the banks of great rivers. Water also holds an important position in our religious beliefs. Several festivals such as the Kumbh Mela are observed while standing in water. Now-a-days, water has come to be seen as the driving force of the economy through its use in agriculture, industry and hydro-electricity generation.

Man has always treated air and water as free gifts of nature which are meant to be exploited to their full extent. The dearth of fresh drinking water is already being felt world on Sohra (Cherrapunjee), which receives some of the heaviest rainfall in the world, lies barren and people have to walk for miles together for a bucket of clean water. For this reason, it is fondly called the "wettest desert in the world".

Fresh water is a very scarce natural resource. However, it has been exploited due to domestic, agriculture and industrial uses and is returned to nature only as waste water laden with all kinds of pollutants. The famous French explorer Jacques Cousteau once said, "Water and air, the two essential fluids on which all life depends, have become global garbage cans". Our waste has choked our rivers and lakes. The fish have either moved away or simply died. The fact that 2003 was declared as the "United Nations International Year of Freshwater" shows as to how this problem has become a global concern even though it is an important input for economic development and environmental sustainability.

1.2 GLOBAL WATER SCENARIO

Water is available in abundance on the earth. Three fourths of its surface is covered with water, more than 97% of this is in the form of the saline water of the oceans, 2% is locked up in ice-caps and glaciers and a large proportion of the remaining 1% lies in deep inaccessible aquifers that are too expensive to be exploited. Thus, effectively 0.2 million cubic kilometers of fresh water is available in rivers, lakes, wetlands, soil moisture, shallow ground water and reservoirs to meet the demands of all the plants, animals and humans inhabiting this planet. This constitutes only about 0.01% of all the water on earth. The World Health Organization (WHO) estimates that only 0.007% of all water on earth is readily available for human consumption globally. Figures 1.1 and 1.2 shows the total water availability and distribution of fresh water on earth respectively. The small amount of available fresh water is constantly being renewed by the hydrological cycle in the form of rain. However, a large portion of rain water either flows back into the sea as run-off or gets evaporated back to the atmosphere.



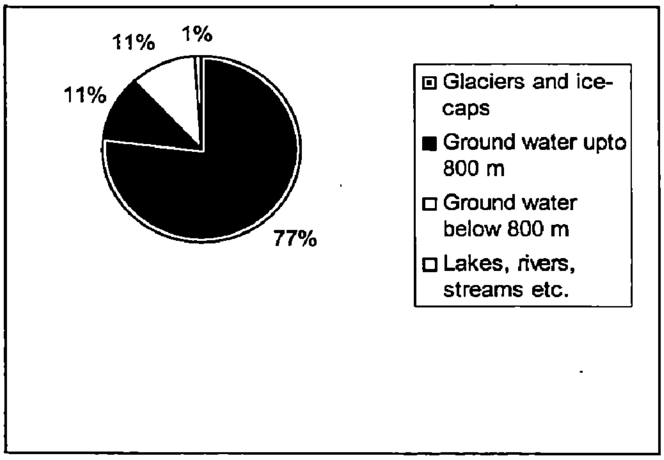


Fig. 1.1 Total water on earth

Fig. 1.2 Distribution of fresh water on earth

Source [3]

With the increase in world population, the demand for clean and fresh water also increases. Yet at the same time, human activities leading to degradation of nature and climate changes have put pressure on the hydrological cycle of nature also the World

Bank Vice President for Environmental Affairs when he said, "The wars of the twenty first century will be fought over water".

1.2.1 WATER SCENARIO OF INDIA

India supports 16% of the world's population in about 2% of the world's land area and contains about 4% of the world's fresh water resources. India is basically an agrarian society with its economy highly dependant on irrigated agriculture. The largest use of fresh water in India is, thus, for irrigation. There are a total of 113 major and minor river basins which form the lifeline of thousands of cities, towns and villages in India. Of these, there are 13 major rivers which share 83% of the total drainage, contribute 85% of the total surface flow and also accommodate 80% of the total population. The details of the major river basins in India are given in Table 1.1 and Figure 1.5 shows the drainage map of India.

Table 1.1 Water Availability In India

Sr. No.	Source of water availability	Quantity (billion M3)
1	Average annual precipitation	4000
2	Average annual water run-off potential	1869
3	Utilizable surface water	690
4	Replenishable ground water	432

Source [3]

Table 1.2 Details of Major River Basins In India

Sr. No.	Name of the River	Length in India (Km.)	Basin Area in India (Sq. Km.)	Average annual Discharge (MCM)	Place of origin	Destination
1	Ganga	2525	861404	493400	Gangotri Glacier Uttar Kashi, U.P.	Bay of Bengal
2	Indus	1270	321290	91455	Near Mansarovar Lake, Tibet	Arabian Sea
3	Godavari	1465	312812	105000	Nasik, Maharastra	Bay of Bengal
4	Krishna	1400	258948	67675	Mahabaleshwar Maharashtra	Bay of Bengal
5	Brahmaputra	720	187110	510450	Kailash Range, China	Bay of Bengal
6	Mahanadi	857	141600	66640	Raipur, M.P	Bay of Bengal
7	Narmada	1312	98796	40705	Amarkantak, M.P.	Arabian Sea
8	Cauvery	800	87900	20950	Coorg, Karnataka	Bay of Bengal
9	Tapi	724	65145	17982	Batul, M.P.	Gulf of Khambhat
10	Pennar	597	55213	3238	Chennakesva Hills, Karnataka	Bay of Bengal
11	Brahmani	800	39033	18310	Ranchi, Bihar	Bay of Bengal
12	Mahi	533	34842	8500	Ratlam, M.P.	Gulf of Khambhat
13	Sabarmati	300	21674	3200	Aravali Hills Gujarat	Gulf of Khambhat

Source [6]

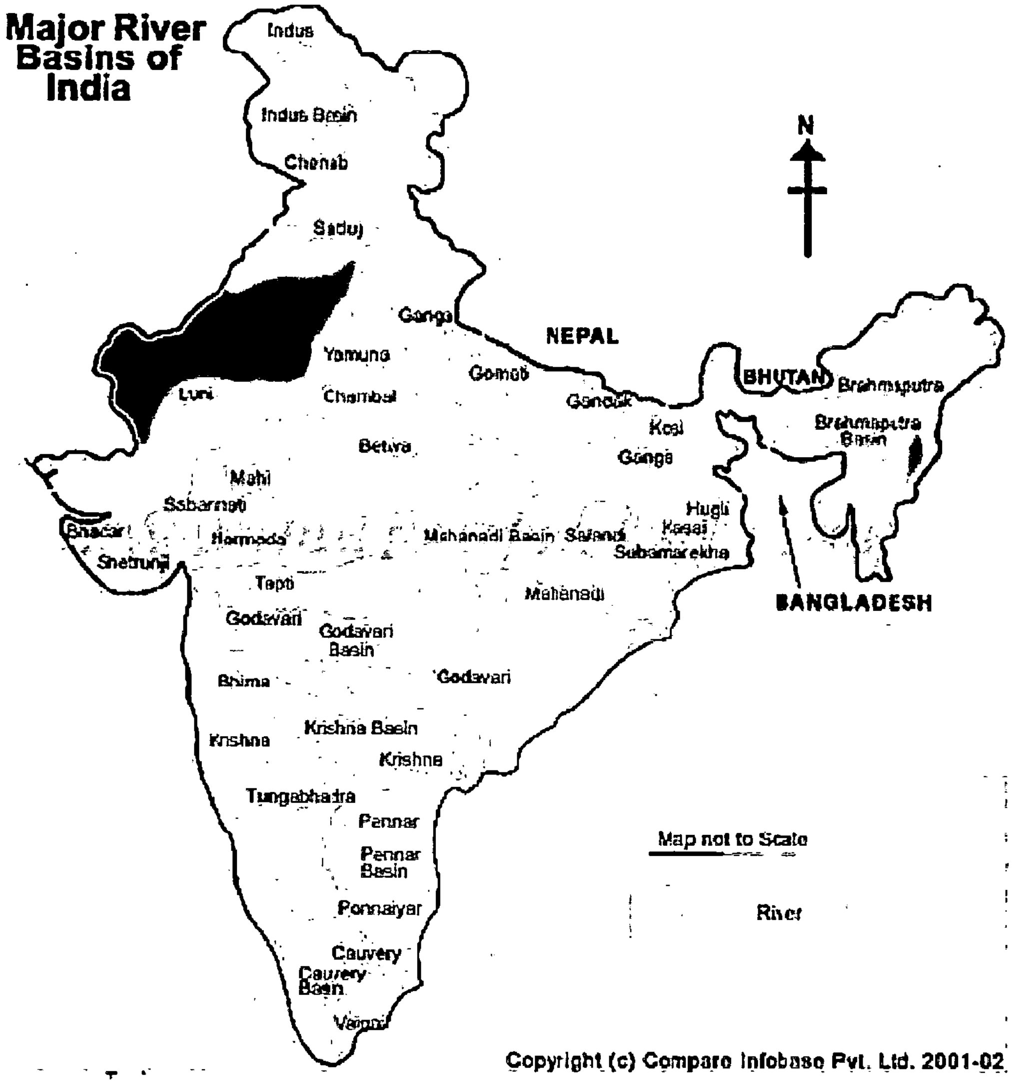


Fig.1.3 River basin map of India

Source [3]

India receives an average annual rainfall of about 4000 billion m^3 from the monsoons. The rainfall is highly erratic and unevenly distributed throughout the country. This has led to increased irrigation and ground water extraction. Of the total rainfall received, 1869 billion m^3 is lost as natural run-off in the streams and rivers, 432 billion m^3 goes for recharging the ground water and only about 690 billion m^3 of the surface water can be utilized. Table 1.2 shows the water availability in the country.

These statistics show that India has a good supply of fresh water but this is far from the truth. Almost 200 million Indians do not have access to safe and clean drinking water and an estimated 90% of the country's water sources are polluted to a great extent. Ground water has been grossly exploited and at a number of places in the country, the amount of water withdrawn exceeds the amount that is recharged.

In India, water quality has deteriorated steadily with time. With increase in population, the demand of fresh water also increased which in turn, led to the increased generation of wastewater. Rapid urbanization in the last century has led to the metropolitan and other bigger cities getting choked with myriad environmental problems such as water supply, wastewater and solid waste generation and their collection, treatment and disposal. A study conducted by the Central Pollution Control Board in 2003-04 indicates that about 26,254 million litres per day of waste water are generated in the 921 Class I cities and Class II towns in India (having more than 70% of urban population) with treatment facilities available for about 7044 million litres per day only. Table 1.3 below shows the trend of water supply, waste water generation and treatment available in Class I cities and Class II towns in India.

Table 1.3: Trend of Water Supply, Waste Water Generation And Treatment In Class I Cities/ Class II Towns

Parameters	Class I Cities				Class II towns			
	1978-79	1989-90	1994-95	2003-04	1978-79	1989-90	1994-95	2003-04
Number	142	212	299	423	190	241	345	498
Population (millions)	60	102	128	187	12.8	20.7	23.6	37.5
Water supply (mld)	8,638	15,191	20,607	29,782	1,533	1,622	1,936	3,035
Wastewater generation (mld)	7,007 (81%)	12,145 (80%)	16,662 (81%)	23,826 (80%)	1,226 (80%)	1,280 (79%)	1,650 (85%)	2,428 (80%)
Wastewater treated (mld)	2,756 (39%)	2,485 (20.5%)	4,037 (24%)	6,955 (29%)	67 (5.44%)	27 (2.12%)	62 (3.73%)	89 (3.67%)
Wastewater untreated (mld)	4,251 (61%)	9,660 (79.5%)	12,625 (76%)	16,871 (71%)	1,160 (94.56%)	1,252 (97.88%)	1,588 (96.27%)	2,339 (96.33%)

Source [4]

In view of the prevailing population growth rate, it has been predicted that by 2025, India will become a water stressed nation. The demand for fresh water will far exceed the availability. Today, India is ranked 122 out of 130 countries for its water quality and 132 out of 180 countries for its water availability.

The Central Pollution Control Board (CPCB) has prescribed different water quality standards for different water uses by introducing the concept of "Designated-Best-Use". This concept states that out of several uses, a particular water body is put to the use demanding the highest quality of water is called its "designated-best-use" and accordingly, the water body has been designated. The Board has identified five such "designated-best-use" classes as shown in Table 1.4 along with their prescribed water quality criteria.

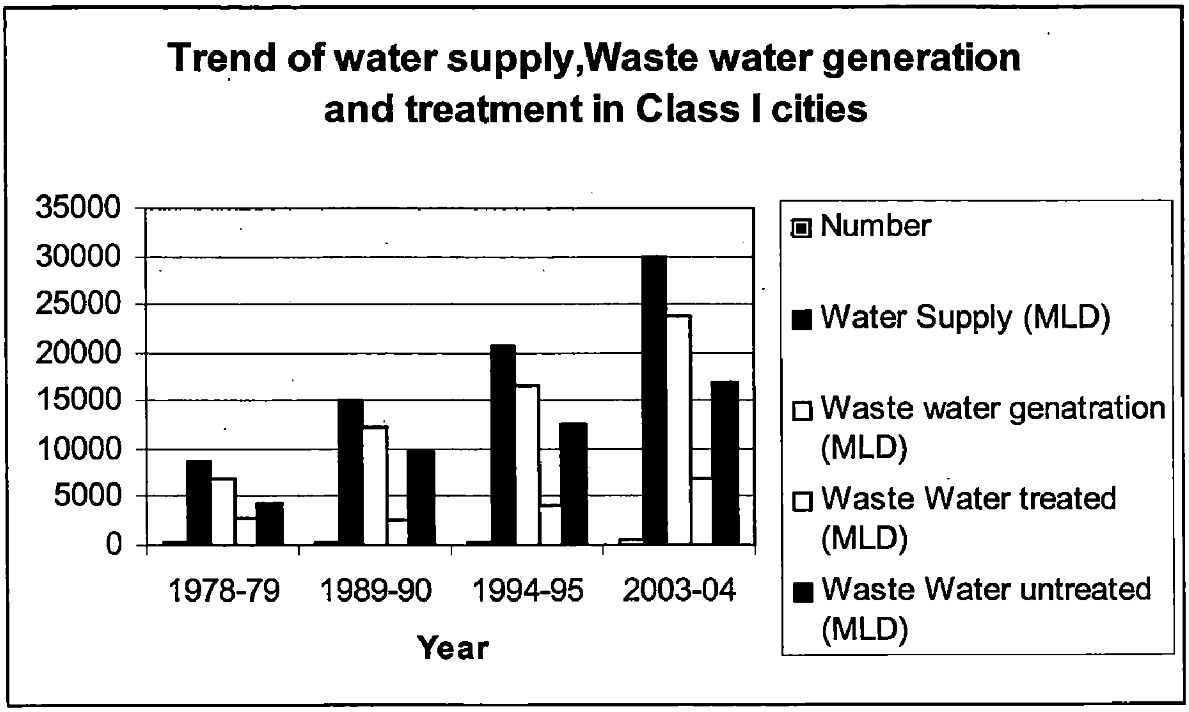


Fig 1.4 Trend of water supply, Waste water generation and treatment in Class I Cities, Source [4]

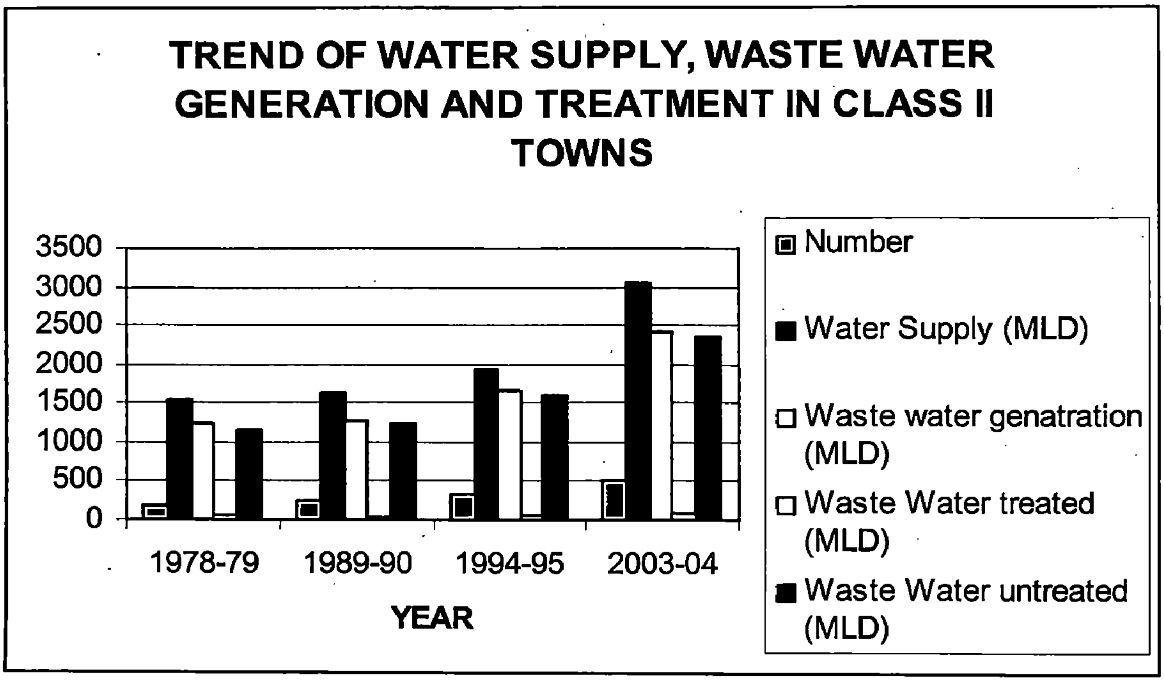


Fig 1.5 Trend of water supply, Waste water generation and treatment in Class II Cities, Source [4]

Table 1.4: Primary Water Quality Criteria for Designated-Best-Use Classes

Sr. No.	Designated-Best-Use	Class of water	Criteria
1	Drinking Water Source without conventional treatment but after disinfection.	A	1. Total Coliforms Organism MPN/100ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6mg/l or more 4. BOD 5 days 20°C 2mg/l or less
2	Outdoor bathing (Organized)	B	1. Total Coliforms Organism MPN/100ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5mg/l or more 4. BOD 5 days 20°C 3mg/l or less
3	Drinking water source after conventional treatment and disinfection.	C	1. Total Coliforms Organism MPN/100ml shall be 5000 or less 2. pH between 6 to 9 3. Dissolved Oxygen 4mg/l or more 4. BOD 5 days 20°C 3mg/l or less
4	Propagation of Wildlife and Fisheries	D	1. pH between 6.5 to 8.5 2. Dissolved Oxygen 4mg/l or more 3. Free Ammonia (as N) 1.2 mg/l or less
5	Irrigation, Industrial Cooling, Controlled Waste disposal	E	1. pH between 6.0 to 8.5 2. Electrical Conductivity at 25°C μmhos/cm Max. 2250 3. Sodium absorption Ratio Max. 26 4. Boron Max. 2mg/l
6	Not for any use	Below E	Not meeting A B C D,E Criteria

Source [14]

1.2.2 WATER AND ECOLOGY

The water of most of the rivers is considered holy. River waters are treated holy by the people in India. Water is the most important input for survival / growth of not only plant, human beings, animals and other living beings on the earth but also economic development and environmental sustainability. Water had both to be managed and exploited for the survival of the human race, on the one hand people had to protect themselves against floods, on the other they had to ensure safe water supply for domestic use and irrigation. Rivers flourised only on the basis of their superior water management systems. Water is considered to be renewable natural resource since it is continually being renewed through nature's hydrological cycle. Also it may be regarded as a unique resource, as the total amount of water available on the "Global basis" remains constant. Degrading the quality or supply of that water can have disastrous effect on the environment and on biodiversity. Irrigation, which consumes for more water than any other use, has generated enormous benefits. Introducing improved varieties, improved cropping patterns and using minimum tillage methods which conserve water, proper water management is essential for adequate availability of quality water for agriculture, industrial and domestic uses, but also for protecting the ecosystem. Water availability is critical to the maintenance of local flora fauna in a watershed particularly fish and other aquatic species. Water is also needed to maintain existing wetlands, flood plains which can have additional positive impact on the watershed because they can recharge aquifers, digest organic waste and store runoff.

1.2.3 HOW FRESHWATER RESOURCES ARE AFFECTED?

The fresh water resources are affected of the selected stretch due to various contaminants added in the water by the human activities like washing of cloths, animals, vehicles, bathing activities mainly at sampling point one and at sampling point six that is at Kushawart and Ramkund respectively, also at some points solid waste disposal and waste water mixed through various nallas. Due to these human actions changes the hydrological cycle and seriously pollute available freshwater. Climate change, global warming also affects the hydrological cycle significantly thereby affecting freshwater production and its distribution. India has declared 2003 as year of the freshwater in keeping with the United Nations Resolution declaring 2003 as international freshwater year. The objective of adopting 2003 as the year of freshwater are increasing awareness among stack-holders regarding scarcity value of fresh water conservation and efficient use of freshwater preservation quality and its ecosystem. Augmentation of freshwater resources, community partnership for informed decision making.

1.2.4 NATIONAL WATER POLICY 2002

The National water policy 2002 recognizes water as a precious national asset. It embodies the Nation's resolve that planning development and management of water resources would be governed by National perspectives. The National water policy, 2002 emphasized integrated water resource development and management for optimal and sustainable utilization of the available surface and groundwater creation of well developed information system, use of traditional methods of water conservation, non conventional methods for water utilization and demand management.

The revised policy integrated quantity and quality aspects as well as en environmental considerations for water through adequate institutional arrangements. Besides 'ecological needs' have been assigned due to priority in water allocation. Greater emphasis has been laid on water quality aspects. The policy also stresses involvement of people in project planning and participatory approach in water resources management.

1.3 LITERATURE REVIEW

The growth of civilization and subsequent needs for better living standard of human being has caused great impact on the environment. The various issues and challenges before the mankind for utilization of natural resources for a sustainable development have compelled to look back at various environmental problems at different levels. One of the major environmental problems is the pollution of surface water body due to discharge of domestic and industrial effluent. According to Odum (1971), "Pollution is an undesirable change in the physical, chemical or biological characteristics of our air, water and land that may or will harmfully affect human life or that of desirable species or industrial processes, living conditions and cultural assets, or that may or will waste or deteriorate our material resources". Human waste was historically the first pollution problem. In ancient times, people naturally settled near source of water and thus, communities grew besides lakes, along rivers, and in areas where spring or well water was available.

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. 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 effluent along the flow path. As a result, due to increasing industrialization and urbanization and other anthropogenic activities, fresh water is becoming an increasingly scarce resource. As population and development pressure continue to grow, most of our water bodies have become polluted (Saluja and Jain, 1998). 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.The riverine resources of India containing 113 river basins out of which 14 are major, 44 medium and remaining 55 are minor rivers. 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) [7]. A river basin of 720000 km2 catchments area characterizes the major rivers (Rao, 1979; Jhingran, 1991 and Gopakumar et al., 2000). [8].

The main cause of river pollution is due to discharge of industrial effluent, domestic sewage, agrochemical and other human activities. 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 the entire 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).[9]

The World Health Organization (WHO, 1985) found that more than 1000 organic compounds are present in river water and effluents. 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). The growth of civilization and subsequent needs for better living standard of human being has caused great impact on the environment. The various issues and challenges before the mankind for utilization of natural resources for a sustainable development have compelled to look back at various environmental problems at different levels. One of the major environmental problems is the pollution of surface water body due to discharge of domestic and industrial effluent. During the Industrial Revolution of the 19th century, cities in the United States and Western Europe grew at a tremendous rate. Refuse of all kinds including great quantities of horse manure ended up in the streets, open sewers and nearby rivers. Devastating epidemics of water borne diseases such as cholera, typhoid and dysentery were common in large cities.

By the early part of the 20th century, the connection between diseases and sewage-borne microorganisms had been recognized. Luis Pasteur (1822-1895) and Robert Koch (1843-1910) postulated the Germ theory of disease. This focused attention of the scientific community to the safe disposal of domestic sewage and need to practice sanitation. Accordingly, safe water supplies were established in most industrialized nations. As a result, water borne diseases have been virtually eliminated in those countries; however, those are still very common in less developed countries, where waste disposal systems are often inadequate or non-existent. In industrialize nations; contamination with hazardous chemicals has become the main threat to the surface water body. Therefore, it becomes necessary to assess and monitor the water quality of the surface water body to determine its acceptability for the different uses as well as pollution status of the water body. If the level of pollution increases above the acceptance level, then necessary control measures have to be established. However, before setting any control measure, we should know the effectiveness of such measures and for this, water quality model has to be developed for the surface water body. Water quality model will help in predicting water quality responses of the water body in different load condition and allow us to choose alternative option.

The literature has been reviewed under two headings namely (1) Study of pollution status of river and (2) Water Quality Index.

1.3.1 STUDY OF POLLUTION STATUS OF RIVER

A number of studies have been carried out in connection with water quality of river. Grande (1964) studied the water quality of river Otra, Norway. He studied the conductivity, colour, COD, organic suspended solids and pH of different water samples of pulp and paper mill wastes on fish population of the river. Similar works were carried out in the river Yodo, Japan (Shoji, 1966); in the river Holme (Brown et al., 1979); in the river Isumi, Japan (Mori et al., 1979) and in Glatt River, Switzerland (Gunten et al., 1986). Schroesfer (1963) carried out some research works in the Mississipi River, Rajagopalan et al. (1973) studied pollution of Subarnrekha River at Rachi. Chattopadhyay et al. (1984) studied the pH, alkalinity, chloride, sulphate, phosphate, nitrogen in different forms, DO, BOD, and COD of the Ganga river water in the Kanpur region and found that the river water in Kanpur region has become highly polluted. Similar works on the Ganga River was carried out in Varanashi region (Sing, 1985).Agarwal et al. (1986) studied the DDT residues in the river Jamuna, Delhi and found that the river contains moderate to high levels of DDT residues. The concentration of total DDT residues ranges from 0.04 to 3.42 milligram per litre in water, 0.007 mg per kg in bottom sediments, 0.05 to 15.24 mg per kg in various invertebrates and 0.54 to 56.31 mg per kg of fishes. Anderson and Peterson (1969) showed by experiments that DDT has sub lethal effects on the nervous system of Brook Trout. Tirath et al. (1982) studied the water quality of Gomti River, Lucknow (U.P.). They studied DO, BOD, nitrogen in different forms, TDS, TSS and turbidity and found that the river water is polluted. Raina et al. (1984) studied the pollution status of the river Jhelum-1. Das et al

Table 1.5 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: [14]

(1987) studied pollution status in river Ib (physico-chemical characteristics). Ajmal et al. (1988) studied pollution of Hindon and Kali nadi. Sankaran (1988) studied pollution on Cauvery and Adyar rivers in Tamil Nadu. Shah (1988) studied physico-chemical aspects of pollution in river Jhelum (kasmir). Sinha (1988) studied effect of waste disposal on water quality of river Damodar in Bihar with special reference to physico-chemical characteristics. Khan et al. (1994) studied water quality parameter (physico-chemical characteristics) in river Ganga between Narora and Kannauj, U.P.

Ghose et al. (1990) studied the water pollution due to the surface and underground mining activity in Satgram Underground Coal Project. Kakoti (1990) studied physico-chemical characteristics of municipal wastewater of Guwahati city flowing through 9 major drains in different areas of the city. Pophali et al. (1990) studied the pollution load in pre monsoon and post monsoon seasons in Patra River, Bhopal, and Madhya Pradesh. Katariya (1994), studied water quality of Kalisot River, Mandideep, Bhopal. Angelidis et al. (1995) studied the impact of point (domestic and industrial effluent) and non-point (agricultural land run off) pollution sources on the quality of the receiving waters of the Evrotas River (Laconia, Greece). Vutukuru et al. (2002) studied the impact of domestic and industrial wastes on the water quality structure of Gostani and Velpur canal, Tanku, West Godavari district, Andhra Pradesh. The canal was subjected to organic pollution, indicated by high BOD and COD values besides poor microbial water quality. Nagaraj et al. (2005) studied the impact of industrial effluents and domestic sewage on ground water pollution in Vrishabavathi river basin, Karnataka.

The State Pollution Control Board, Maharashtra has made some water quality measurements in the Godavari River and its other tributaries, under Environmental monitoring, GEMS and MINNARS Project. The analysis results of all the sampling points of the various rivers including Godavari River under these projects are available on MPCB and CPCB websites. Das (1977) studied the pH, DO, BOD, oil and phenol in the water of the Godavari River. He found that amounts of these parameters were considerably high in comparison to the CPCB standards. Sharma et al. (1994) studied the physico-chemical parameters of Godavari River water. The results showed high pollution status with values of some parameter beyond the permissible limits DO (1.0 mg/l), Alkalinity (430 mg/l), BOD (12.2 mg/l) and COD (62.0 mg/l) etc.[5]

1.3.2 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) .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 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 .This effort was supported by the National Sanitation Foundation (NSF). As a result, the brown index is also referred as NSFWQI. This is most favorable in assessing the water quality in a polluted water bodies.

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

Public awareness and consciousness about pollution in general and pollution of water in particular has increased over the recent years. Emergences of International Organization like Green Peace are testimony to this fact. However, in spite of awareness of water quality and water pollution, the general public is at loss to understand the actual level of water quality as it is explained in technical parameters. In such circumstances, if the water quality is expressed in terms of numbers, the public as well as technologists and administrators can better understand it.

An index is a mean device to reduce a large quantity of data down to a simplest form. First the term environmental indicator or sub-index function is calculated which refers to a single quantity derived from one or two polluted variables/characteristic parameters (Ott-1978). It is used to reflect some environmental attribute. Water Quality Index (WQI) is then calculated by a mathematical aggregation of two or more indicators in some fashion. It is simply a numerical value having no units. WQI is a comparison of water quality or status to a prescribed base or to a scientific arbitrary standard. Various ranges of 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 etc.

1.3.2.1 HISTORY OF DEVELOPMENT

It is reported that attempts were made in Germany as early as 1848 to relate the level of water pollution to the occurrence of certain biological organism (Landwehr-1974). Since then, various European countries have developed and applied different system to clarify the quality of surface water. Indices, which use a numerical scale to represent the gradation in water quality levels, were first introduced by Horton (1965). In India, Bhargava (1985) has suggested a water quality index for river Ganga for zoning and classification with respect to specific use.

1.3.2.2 USES OF WQI

The planning Committee of National Academy of Sciences (NAS) 1975 has indicated that the Environmental indices perform an important role in formulating policy, judgment of effectiveness of environmental protection programmes, designing such programmes, and communicating with the public concerning conditions of the environment and progress towards its enhancement.

1.3.2.3 Types of WQI

The different water quality indices developed into four general categories:

1) General water quality indices,

2) Specific-use indices,

3) Planning indices, and

4) Indices based on statistical approach

All the details of various water quality indices including NSFWQI are given in chapter 3.

1.3.3 TREND OF POLLUTION

The water of the Godavari River in Nasik city has gradually deteriorated due to industrialization and urbanization of the Nasik city. The study revealed that the streams of Nasik city are polluted with municipal wastes. The water of Kapila River and other resources have also deteriorated due to increasing urban and industrial activities Nasik city. The river Godavari in Nasik city is also polluted due to the similar reason.

The river Godavari at Maharashtra, Jamuna at Delhi, Hooghly at kolkata, Ganga at Kanpur, Allahabad and Varanasi 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.

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.

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.

1.3.4 STUDY OF WATER QUALITY MANAGEMENT OF RIVER

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 [1]. 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) [7]. The sources of river pollution in India are tabulated in Table 1.1.

1.3.5 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) [18].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.

1.3.6 DEVELOPMENT OF BOD AND DO MODEL

The mathematical modeling of water quality in a river has progressed from the pioneering work of Harold Streeter and Earle Phelps (1925) who developed the relationship between the decay of an organic waste measured by the biochemical oxygen demand (BOD) and dissolved oxygen (DO) resources of the river, producing the classic dissolved sag model. These two counteracting processes, (BOD and DO), are considered in the traditional BOD-DO model of Streeter and Phelps (1925) in the mathematical form. Subsequent to Streeter and Phelps (1925), several BOD-DO models and several concepts were introduced in the past (Theriault, 1927; Camp, 1963; Li, 1972; Gundelach and Castillo, 1976; Van Genuchten and Alves, 1982; Bhargava, 1983; Thomman and Muller, 1987; Jolankai, 1997, Yu et al., 1991; Adrain et al., 1994). Most of these models have gradually increased in terms of the number of variables representing the variation of BOD as well as DO concentrations. However, some of the models are different in functional forms and do not transform to the widely used Streeter and Phelps model.

To assess the changes in water quality of rivers in spatial and temporal scales, very limited modeling efforts have been made in India in recent years (Bhargava 1983; Choudhary et al., 1990; Ghosh, 1993; Jain, 1998; Sharma et al., 2000). Abbasi et al., (2002) studied the modeling of Bukingham canal water quality, Chennai, India by using the QUAL2E-UNCAS software. Numbers of software are available for water quality modeling of river and stream. They are QUAL2K, QUAL2E, WASP, CE-QUALM-ICM, HEC5Q, MIKE11, ATV MODEL, SALMON-Q, DUFLOW, AQUSIM and DESERT etc. These software's have been developed for the Environmental Protection Agency (EPA) of United States of America. QUAL2K is a modeling Framework for simulating river and stream water quality developed by Steve Chapra, Greg Pelleties and Hua Tao.

TIVE OF THE STUDY

r of the River Godavari has been used for domestic, industrial and irrigation purposes. However, with the increase in the population of Nasik and its haphazard growth, in some of the areas of the Nasik City mostly slum areas and undeveloped areas this river has been converted into a drain used for dumping almost everything in some areas mostly at downstream of the Nasik city. The objective of present study

To study the effects of all these anthropogenic sources of pollution at several points from Kushawart Trimbakeswar to Saikheda Village total 65 Kms stretch at ten locations of the River.

To find out point sources and non point sources for selected study stretch.

To assess the water quality of selected locations as a primary data for 2-3 times between eight months period.

To collect secondary data for last 5-6 years from MPCB office and CPCB websites.

To use online software of NSFWQI to find out water quality indices and water quality on the basis of indices.

To represent NSFWQI on water quality graphs and maps to find out the trend of water quality of selected stretch.

To compare primary and secondary data for the year 2003 and year 2007 for to assess water quality management measures taken by NMC Nasik.

To suggest conservation measures and recommendations by considering the performance of present measures taken by Nasik Municipal Corporation mainly three sewage treatment plants of capacities 78 MLD, 7.5 MLD and 22 MLD at Tapowan, Panchak and Chehadi respectively in addition to that one solid waste treatment plant and one bio-medical waste treatment plant, which will help in preparing and implementing the mitigation measures for improving the water quality of the river based on the study.

Total Sewage gen Nasik
Total BMW genⁿ
Total MSW

1.5 NATIONAL RIVER CONSERVATION PLAN (NRCP)

The Ministry of Environment and Forests, Government of India, started a programme for cleaning up of rivers in the country with the implementation of the Ganga Action Plan (GAP) in 1985. A Central Ganga Authority (CGA) was set up under the Prime Minister with the members being the Chief Ministers of the concerned states, Union Ministers and Secretaries of the concerned Central Ministries along with experts in the field of water quality. GAP was extended to GAP Phase – II in 1993 and then to NRCP in 1995. GAP Phase – II was merged into NRCP in 1996. The objective of the NRCP was to improve the water quality of major rivers as the major fresh water source in the country, through the implementation of pollution abatement schemes. Since then, a single scheme of NRCP is under implementation as a Centrally Sponsored Scheme. The CGA was renamed as National River Conservation Authority (NRCA) with a larger mandate to cover all the programmes supported by the National River Conservation Directorate.

The functions of the NRCA are as follows:

(1) To lay down, promote and approve appropriate policies and programmes (long and short-term) to achieve the objectives.

(2) To examine and approve the priorities of the NRCP.

(3) To mobilize necessary financial resources.

(4) To review the progress of implementation of approved programmes and give necessary directions to the Steering Committee, and

(5) To make all such measures as may be necessary to achieve the objectives.

GAP Phase I: - Was started in 1985 as a 100% centrally funded scheme. The main objective was to improve the water quality of the River Ganga to acceptable standards by preventing the pollution load from reaching the river. Under GAP Phase– I pollution abatement works were taken up in 21 Class – I towns in Uttar Pradesh, Bihar and West Bengal. GAP Phase – I was extended to GAP Phase – II, approved in stages between 1993 and 1996. It covered the River Ganga and its major tributaries, viz. Yamuna, Gomati and Damodar. This plan covered pollution abatement works in 95 towns along the polluted stretches of these 4 rivers spread over 7 states. Accordingly, GAP was merged into a National River Conservation Plan (NRCP) in 1995 on 50:50 cost sharing basis between Centre and State Governments. The Ganga Project Directorate was converted into the National River Conservation Directorate (NRCD) for servicing the National River Conservation Authority and the Steering Committee. It covered pollution abatement works in 46 towns along the polluted stretches of 18 rivers spread over 10 states. The GAP Phase –II was merged with NRCP in 1996. NRCP was converted into a 100% centrally funded scheme in November 1998 with only the land cost to be borne by the States. However, in March 2001, it was decided to adopt an integrated approach for the river cleaning programme and that all future programmes will be shared on a 70:30 cost sharing basis between the Centre and State Governments respectively. [14]

CHAPTER 2

STUDY AREA OF RIVER GODAVARI

2.1 INTRODUCTION

River Godavari at Nasik is contained to be one of the major rivers in India, which attaches considerable significance to the Hindu mythology, and the religious sentiments of bathers.Nashik has a glorious history of 4500 years. Nashik is an important pilgrimage center where large number of devotees who come across from all over world. The number of pilgrims rises to lacks at the time of Kumbhmela. Kumbhmela occurs after every twelve year. According to one interpretation the place was named Nashik because it is situated on the nine peaks known as Narshikhara. The other interpretation is that the place got its name as Laxman cut off the nose of Shrupankha during the Ramayan period. Nasik has developed on both sides of river Godavari which is considered to be scared as Lord Ram along with Laxman and Sita are believed to have stayed at Panchavati situated on left bank during their exile. Sita was abducted by Ravan from this place. In around 1637 AD the mughals overthrew the regime of then rulers of NIZAMSHAHI dynasty and merged Nashik with Aurangabad. In 1818 AD Holkar's Nasik possession passed into hands of the British Empire. According to legend Lord Indra was running with Amrit Kumbha and was being chased by Danavas. A few drops fall in Godavari (Ramkund) and people rushed to get these drops of Amrit. The kumbhmela is held since then. It is believed that the water of Godavari has a purifying value during this period that the sacred rivers like the Ganga, Yamuna, Narmada & Saraswati come to wash in Godavari. Most of the temples of Nasik were built around 1216 AD by Yadav's of Devgiri and some of the important temples are Trimbakeshwar, Kapaleshwar, and Someshwar.

2.2 ORIGIN AND IMPORTANCE OF RIVER GODAVARI

The second largest river in India, Godavari is often referred to as the Vriddh (Old) Ganga or the Dakshin (South) Ganga. The name may be apt in more ways than one, as the river follows the course of Ganga's tragedy: Pollution in this peninsular river is fast reaching unsafe levels. The Godavari originates near Triambak in the Nasik district of

Maharashtra, and flows through the states of Madhya Pradesh, Karnataka, Orissa and Andhra Pradesh. Although its point of origin is just 80 kms away from the Arabian Sea, it journeys 1,465 kms to fall into the Bay of Bengal. Some of its tributaries include Indravati, Manjira, Bindusara and Sarbari. Some important urban centers on its banks include Nasik, Aurangabad, Nagpur, Nizamabad, Rajahmundry, and Balaghat.

Like most other rivers, domestic pollution is the biggest polluter of the river Godavari, accounting for 82 per cent of total pollution, whereas industrial pollution accounts for about 18 percent. Over half of the river basin (18.6 million ha), is categorized as cultivable land. Most of the river's water is drawn for irrigation purposes. The river water is heavily used for agriculture, as it is the only available water source.for setting water quality objectives of a water body, it is essential to identify the uses of water in that water body. Normally each stretch is used for various purposes. Out of these, the use which demands highest water quality is termed as Designated Best Use and accordingly the water body is classifies. The CPCB has identified five such "designated best use" as given in Table 3.1. Water, being a best solvent available on earth, is seldom found in pure state, it exists as a mixture. In nature, the most nearly pure state of water is in its evaporation state. For water to condense, it requires a surface or a nuclei, thus water may acquire impurities at the very moment of condensation. In the hydrological cycle, water comes in contact with various gases and particulate matter in the atmosphere, soils, rocks and other materials on land and various minerals underground. During this contact, water acquires impurities. The characteristics of water of a particular place depend on the types and quality of the materials it has come into contact with. Human activities contribute further impurities to the water. Industrial and mining wastes, domestic wastes, agricultural chemicals and other contaminants added by humans have greatly affected the quality of water bodies.

2.3 STUDY AREA

Study area for the present work covers stretch of 65 Km falling within the Nasik District is considered to be sacred and pilgrims in large numbers. It results it has become dustbin for eventual disposal of all sorts of pollutants (waste water, debris etc.) due to the rapid and unplanned growth of human settlements along both sides of the river banks, insufficient sewage disposal and treatment facilitates lack of bathing ghats, Dhobi Ghats (place for washing cloths), Place for washing of animals, vehicles etc. Last Kumbhmela was in the year 2003-2004, during that period lot of work completed for conservation of Godavari River like 78 MLD Sewage Treatment Plant at Tapowan, Nasik,7.5 MLD STP at Dasak Village and 12 MLD STP at Takali Village, apart from this Solid Waste Treatment Plant and Bio- medical waste treatment and disposal plant were installed. I have to concentrate on the study of water quality assessment of the Godavari River so that reduce the pollution in the river Godavari for a particular case only. That is from Kushawart to the Saikheda village total 65 kms stretch. Within which the major nallas causing the pollution meets the river in the city area only.

To identify the sources of pollution and management of water quality, this dissertation will be carried out. In this dissertation the survey of area around river Godavari that contributes the discharge of sewage in it is required. Their pollution strength will be determined by performing tests from the samples from these polluted sources. The tests will be performed on the samples for about 8 months to study the variation in the pollution strength due to variation in flow condition and seasonal change. The following tests will be carried out:

1) pH
2) Dissolved Oxygen (DO)
3) Biological Oxygen Demand (BOD)
4) Chemical Oxygen Demand (COD)
5) Total Hardness
6) Calcium Hardness
7) Magnesium Hardness
8) Electrical Conductivity
9) Alkalinity

10) Chlorides

11) Sodium

12) Potassium

13) Sulphates

14) Phosphates

15) Nitrate

16) Total Suspended Solids

17) Total Dissolved Solids

2.3.1 Status of Pollution in Godavari River

Godavari River has been considered as holy and is supposed that a dip in river Godavari make people free from sins. But today a dip in this river will make people free from their skins. The stretch of 65 km falling within the Nasik Collectorate limits was taken for study in this dissertation work. Pollution of the river starts from Kushawart where people take holy bath and wash cloths, which is a religious cum tourist spot. Domestic waste of Someshwar released in the river without any treatment. Chikalli nalla, which joins the river Next to Someshwar and before Anandwali station, sometime release wastewater from Satpur and Ambad MIDC industrial areas. At Anandwali station everything, which is waste or unwanted, is dumped at the bank of the river and also the pollution in the river is due to the domestic sewage discharged in it. At Ramkund station large no of Pilgrims converge to take holy dip in its water and performs various religious rites besides worshiping and burning of dead bodies etc. While on the other hand it has become a dustbin for eventual disposal of all sort of pollutants (debries, wastewater, Nirmalya, Asthi and Raksha – Visarjan etc.) necessitated due to the rapid and unplanned growth of human settlements along both sides of the riverbank, inadequate sewage disposal and treatment facility, lack of bathing ghats and direct discharge of Waghadi nalla water.

Table 2.1 Classification of water body based on "designated best use"

Sr. No.	Designated Best Use	Quality Class	Primary quality criteria
1	Drinking water source without conventional treatment but with disinfections	A	PH 6.5–8.5; DO≥6.0; BOD< 2; MPN< 50
2	Organized outdoor bathing	B	PH 6.5–8.5; DO≥ 5.0:BOD≤3.0;MPN<500
3	Drinking water source with conventional treatment followed by disinfections	C	PH 6.5-8.5; DO≥6.0; BOD≤5.0; MPN<5000
4	Propagation of wildlife and fisheries	D	PH 6.5–8.5; DO≥6.0; $NH_4^+ \leq 1.2$
5	Irrigation, Industrial cooling and controlled water disposal	E	PH6.5–8.5;Na absorption ratio max 20

2.3.2 Data Collection

On the industrial area Nashik has acquired a great importance on the industrial map of India. Two industrial areas in Nashik namely Ambad and Satpur Industrial Areas has been developed in Nashik Municipal Corporation. Due to which the population of Nashik city has increased considerably in the short period. The population according to 2001 census has crossed the mark of 14, 00,000. Leading to the development of large numbers of residential areas without considering drainage system.

Nasik an industrial and developed city in the state of Maharashtra and the Godavari River is flowing through the city. The development is growing after establishment of the industrial area like Satpur and Ambad MIDC. Industrial development in that area mainly large and medium scale industries like Motor Industries Company Limited (MICO), Mahindra and Mahindra, VIP Industries, Ceat Limited, Carbon Corporation Limited, ABB Limited, BCL Forging Limited, Gloxo Limited, Siemens, Garware Polyester Ltd, Gabriel and so on, nearly 125 large scale and 350 medium scale units along with 2500 small scale units are presently running in these industrial estates. All these units are at the upper part of the City and Bank of Godavari River. All this large scale, medium scale units and other small scale 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, pathological laboratories and nursing home etc are growing in and around the Godavari River. The water of Godavari River was being used by people for domestic purposes such as drinking, bathing, cleaning and other aesthetics purposes.

The present dissertation is concerned waste water quality management of river Godavari in Nasik City. That is from Kushawart Trimbakeswar (source of water) to the Saikheda village within which the several activities like washing of cloths, washing of vehicles, washing of animals, Bathing activities, sewage disposal of nallas causing the pollution meets the river in the area only. The work included identification of pollution sources based on the survey of area around river Godavari contributing the discharge of sewage. The sampling points were located on the stretch. The CPCB as well as MPCB data considered as secondary data where as data collected for assuming the pollution load of these locations was processed to computing the NSF water quality indices. The samples were taken these locations in the month of December 2007 and February 2008 only. The main parameters were carried out like pH, Total Suspended Solids, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Hardness, Nitrate, Phosphates, Electrical Conductivity, Faecal Coliform, Chlorides, and Sulphates etc.

These data was converted with National Sanitation Foundation Water Quality Index to achieve at a single value defining the water quality at selected locations.

2.3.3 CLIMATE

Nashik has a mild climate with plenty of sunshine all through the year. In summers May is the hottest month with maximum temperature. The months of September to March are the best to visit Nashik and nearby areas. The monthly maximum temperature reported to have been recorded was in the month of May 2008 was 41.5 deg.C and monthly average minimum temperature recorded in jan.2008 was 6.5 deg.C. The weather is observed cold from Dec. – Feb. and is hot / dry from March to May. Rainy / monsoon season from June to September is due to South – West monsoon. The weather is fair after the rainy season i.e. October and November. Relative humidity is maximum 62% and minimum 23.65%

2.3.4 INDUSTRIES LOCATED AT NASIK

Two industrial estates of Satpur and Ambad developed by MIDC come within the limits of Nasik Municipal Corporation limits, these industrial area establishments in the year 1962 and 1978 respectively. The total employees employed in this industrial area are more than one lacs. The city industrial and development corporation (CIDCO) has also developed residential area to meet the influx of population due to establishment of the two industrial areas of MIDC at Satpur and Ambad. This residential area developed by CIDCO is included in the trend of development. The industrial development is responsible for the rapid growth of the population in the NMC area. Simultaneously there is increase in the slum area.

All the drinking water supplied to Nasik city is from Gangapur Dam. Which is an earthen dam was built across river Godavari which was completed in year 1965. The dam was built with purpose to supply water for irrigation, domestic and industrial use of Nashik City. The Catchment area: 357.40 sq. KM, Submergence area: 2231 Ha,Left Bank Canal: a) Length 64 Km, b) Discharge 8.92 M3/sec,Right Bank Canal: a) Length 30 Km, b) Discharge 3.68 M3/sec, Radial gates: 9 No.'s, Storage capacity: 215.88 million M3, Live storage: 203.88 million M3, Dead storage: 12 million M3, Year of completion of dam:1st stage: 1954 and 2nd stage: 1965, Cost of the project: 5 Crores.

2.3.5 SOURCES OF POLLUTION

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.

Some of the important Domestic sewage discharge, washing activities of vehicles, cloths and animals, bathing activities Pollution causing factors were observed, in some places solid waste disposal and bio- medical waste disposal were also observed. presently no open nalla discharge observed in the area except some washing activities, because lot of work done during the period of Kumbhmela like 3 STP's, Solid waste and Bio-Medical waste treatment and disposal plant.

Major Sources of Pollution in River Godavari Location of Point Sources

The fieldwork was done along the banks of the river to identify the source of pollution in the river. The stretch of 65 KM is considered in this dissertation work. As already said the present pollution occurring in Godavari River is mainly due to the domestic sewage and washing activities only like washing of cloths, animals, vehicles etc.

The major nallla's were discharging domestic sewage in Godavari before the years 2003 are namely Nalla at Kannamwar Bridge, Shreerangnagar Nala, Chikhali nalla, Malharkhan Nala, Anandwalli nalla, Saraswati Nala, Waghadi nalla, Bhoi Nallas at Downstream of Nashik, Nalla at Amardham.

All these above nallas were diverted to newly installed 78 MLD STP at Tapowan for treatment of waste water, after proper treatment waste water disposed off in to Godavari River. Present locations of the point sources are Kushawart, Someswar, Anandwali, Victoria Bridge, Ramkund, and Tapowan, Dasak Village, Saikheda Village of Nasik also at some times discharges effluent at Anandwali point in the Godavari

2.4 POLLUTION OF STUDY STRETCH

The water of the Godavari River is gradually deteriorated due to industrialization and urbanization of Nasik City. 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 city area out let to Nasik city area along the flow path of Godavari River.

SOURCES OF POLLUTION

The sources of pollution of the Godavari River can be classified as;

1. Point sources
2. Non point sources.

Point Sources

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

1. **Industrial plants :** Industries such as Motor Industries Limited (MICO), Mahindra and Mahindra, Ceat Limited, Graphite India Limited, Siemens, Garware Polyester Limited, Kirloskar Oil Engines, Gabriel, Taj Residency, Atlas Capco, Asian Electronocs, Pferd Tools, Caprihans Limited, Jyoti Structures Limited, Jyoti Ceramics

Limited and other medium and small industrial units which treated their industrial and domestic waste water as per Maharashtra Pollution Control Board norms and used for gardening in their own premises no waste water directly discharges in to the Godavari River. However some times some small scale units illegally discharges their untreated or treated waste water during night time in to the Godavari River.

2. **Drainage system:** The sewage from Nasik city municipal area is going to the Godavari River with treatment after 78 MLD Sewage treatment plant. The domestic sewage of some parts of the municipal area not treated and same is discharges directly in to the river. The Nasik Municipal Corporation is trying to collect all sewage from the municipal area for treatment and proper disposal in to the river, consequently, because of this; river area is highly polluted by the sewage water.

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

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 Godavari 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:** These sources are limited with respect to other sources because of very less amount are used such types of chemicals. Besides, about 20 square km area are used as cultivated land. 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.

2.5 POLLUTION BY INDUSTRIES

As already explained above the Godavari River is less polluted by the above major industrial units and these sources not dominated major portion of pollution load in respect of the Godavari River. But mainly the sewage of the Municipal area is the problem in regards of the Godavari River Pollution.

BIO-MEDICAL WASTE

There are thirty large hospitals and more than 500 nursing homes and fifty pathological labs are performing their functions in the entire Nasik City area. The total bed of said nursing home and hospitals are about 2000, for this one common Bio- Medical Waste treatment and disposal Facility is working under Nasik Municipal Corporation , but presently 60 – 70 % Hospitals are giving their BMW regularly to this facility. There is a more scope for conservation measures in this area, details are given in the chapter 7.

Automobile Waste Water

There are 50 numbers of motor garages and 30 numbers of servicing centre which are operating in the Nasik Municipal area. Consequently, the waste water is discharged to their respective drain which is ultimately going to the Godavari River. Some large service stations are having their own treatment plants, some small units are in process to do the treatment plants as per pollution control board norms.

Industrial Estate, Satpur and Ambad

There are 50 plastic industries and few small chemical industrial units in the estate but their discharge amount is very negligible and other industries also show similar nature in respect of such effluent discharge.

POLLUTION BY DOMESTIC SOURCES

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

Rural Area

There area about 50 thousand people live in and around the Godavari River along its 65 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 Godavari River as sewage 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 Godavari River (as referred from the project report, studies on the water quality analysis of Godavari river, August, 2004) [46].

Urban Area

The total population of Nasik municipal area and new developing area is 15 Lacs. The water is used per day for domestic purposes as based on of a gross of per capita average demand of 150 lpcd. About 60-70 % waste water generated from the municipal area is treated through various sewage treatment plants, for remaining water corporation work is in progress. The details are given in the conservation measures chapter 7. Therefore, the water quality of the Godavari River has been gradually increasing regularly.

Pollution by Agricultural Chemicals

The fertilizers and agricultural chemicals such as pesticide, weedicide and insecticides may be ignored along the flow path of the Godavari River in rural area under the catchments area of the Godavari River. There are no pesticides; weedicide and insecticide are found in the water analysis of the Godavari 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 Godavari River is 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 Godavari River.

Organic Pollution

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

Domestic

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

Rural area

The BOD contribution of rural area has been considered as 15 grams per person in a day into the Godavari 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] [9].

There are 50 thousands people live in rural area of the Godavari River and the BOD load is contributed by the rural people to the Godavari River.. Again this organic load is distributed as a divergent nature and easily removed their adverse affect by the self purification process of the river.

Urban area

The total population of Nasik Corporation area is 15 Lacs and contributes more BOD load in a day into the Godavari River. This amount concentrates as a point source in a close area of Godavari River. Consequently, it affects the entire ecosystem of the Godavari River

Oil pollution

The Godavari River receives very less amount of oil and grease mainly from various servicing stations. Both pollutant are important and affect adversely on the Godavari River ecosystem. Analysis results show both parameters under permissible limits but water quality of the river is gradually deteriorated due to this pollutants

2.6 PAST AND PRESENT SCENARIO OF THE RIVER GODAVARI

The whole stretch of the study area of river Godavari is divided into three parts according to the water use by the people residing nearby area of the river as shown in Fig. 4.1.

Stretch No.1: The river water is used for drinking, bathing, washing clothes and other useful purposes in upper stretch of the river and till now the water quality in this stretch is not deteriorated due to less anthropogenic activities that is up to the Someswar sampling location. This upper basin is characterized in Class I area; only few human settlements are taking place in this area due to inaccessibility and poor infrastructure (road, electricity and communication). The water body of this stretch of the river can be classified as class 'A' on the basis of DBU. This stretch has a length of about 34 km from the origin. The clear water of this stretch is shown in the photograph.

Stretch No.2: The river water in this stretch is also used for drinking, bathing, washing clothes and other purposes. However due to the growth of the city in the downward direction and settlement of people in that locality, the river water gets polluted due to the discharge of domestic sewage. It leads the water body unsuitable for drinking purposes and is used for washing clothes, washing animals, washing vehicles, bathing and other purposes. This stretch has a length of about 5 km and can be classified as class 'B' on the basis of DBU. The water quality in this stretch is slightly turbid and shown in the photograph.

Stretch No.3: In this stretch, the river water is used for bathing, washing clothes, washing animals, washing vehicles, irrigation & other useful purposes.

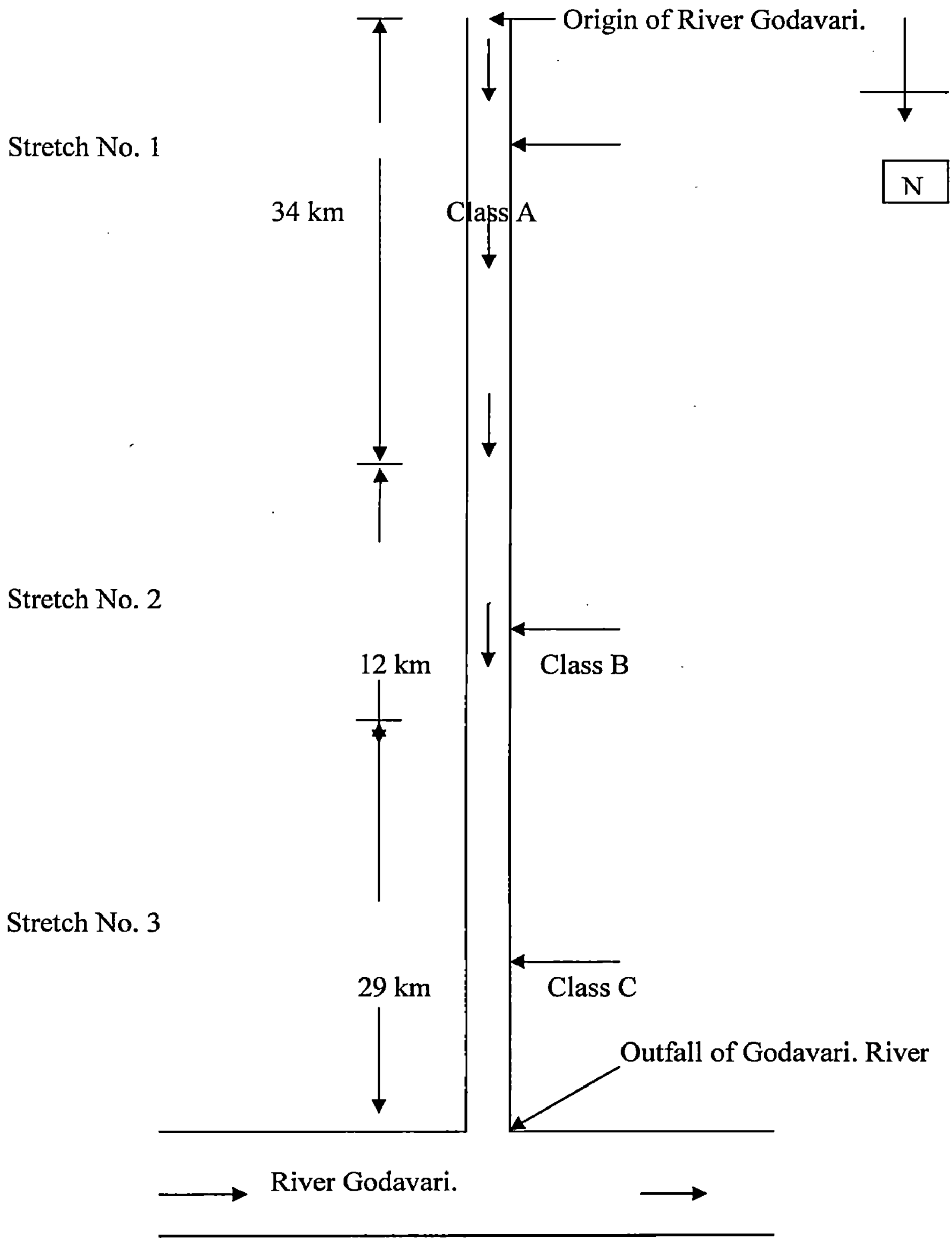


Fig. 2.1 Water quality based classification of river Godavari.

2.6.1 PAST STATUS OF THE RIVER GODAVARI

Major Sources of Pollution in River Godavari

An extensive fieldwork was done along the banks of the river to identify the source of pollution in the river. The stretch of 65 KM is considered for this dissertation work. As already said the pollution occurring in Godavari was due to the domestic sewage, solid waste, and plastic waste and Bio Medical wastes also.

The major nalllas were discharging domestic sewage in Godavari before the years 2003 are as follows:

1) Chikhali nalla
2) Anandwalli nalla
3) Shreerangnagar Nala
4) Malharkhan Nala
5) Saraswati Nala
6) Waghadi nalla
7) Bhoi/Nallas at Downstream of Nashik
8) Nalla at Amardham
9) Nalla at Kannamwar bridge

All the above nallas discharge their sewage in to the most holy stretch of the Godavari river for example gangapur naka, discharge was measured, near slum area at rathi farm, and shrirangnagar nalla was measured near old gangapur Naka etc.

.Water supply and sanitation

As in the case with other hilly regions, the main sources of water supply are rivers, streams and natural springs. Ground water contribution towards domestic water supply is very less. The supply is augmented by the various water supply schemes installed by the Public Health Engineering Department, Government of Maharashtra around the city. As these sources are mainly rain-fed, there is acute water shortage in many parts of the city during the dry winter and spring months. While the responsibility of supplying drinking water in the municipal limits lies with the Nasik Municipal Corporation.

2.6.2 PRESENT STATUS OF THE RIVER GODAVARI

The water of the River Godavari has been used for domestic, industrial and irrigation purposes since time immemorial. However, with the increase in the population of Nasik and its haphazard growth, in some of the areas of the Nasik City mostly slum areas and undeveloped areas this river has been converted into a drain used for dumping almost everything. From domestic waste water to direct discharge from latrines, from municipal solid waste to construction debris, this river accepts all types of wastes. The present study aims at studying the effects of all these anthropogenic sources of pollution at several points along the river and some of its tributaries. The study includes the use of water quality indices to study the quality of the river water and to represent these indices on water quality maps for better understanding and interpretation. Based on the findings, conservation measures and recommendations, which will help in preparing and implementing the mitigation measures for improving the water quality of the river, have been suggested.

2.6.3 IMPACT ON GODAVARI RIVER WATER

The water retained increases the settlement of suspended material, thus decreasing turbidity and improving its quality. The impact of reservoir regulations reduces the habitat for water birds. It is the sign of degradation in the ecosystem. The concept of reserving water for environmental flow can be realized quickly enough to sustain the river ecosystem before irreversible damage is done to the river system. Environmental flow released from the reservoir during closure period of the reservoir to the downstream of the river will maintain the river ecosystem. It reduces the flooding in the reservoir water spread area during monsoon period.

The water replacement renewal period of the reservoir also reduced. It improves the quality of the water. It improves the dissolved oxygen content of the reservoir water quality and it also reduces the turbidity. It reduces algal blooms in the reservoir. The upstream reservoirs also made to release environmental minimum dependable flow in the river system to maintain ecological sustainability of riverine ecosystem. This environmental flow improves the downstream fish production and quality of the reservoir water. Continuous inflow and releasement will improve the water quality of the reservoir instead of heavy impounding storage. Heavy impounding without releasement and without inflow, the renewal of water gets extended. It leads detoriation of quality. Minimum quantity of fresh water has to be enforced in to reservoir from upstream reservoir at least with reference to releasement for environmental flow release for downstream river ecological requirement. The environmental flow will take care of dilution of contamination and self purification of the river as well as life in the river system. Complete closure of the reservoir releasement will affect the quality of the reservoir water. The reservoir should have necessary minimum environmental flow entry in the upstream side and also necessary environmental flow to be released from the reservoir in the downstream side ecosystem sustainability.

In Stanley reservoir due to lack of entry of minimum environmental flow from the upstream reservoirs and poor releasement for only water supply to the downstream some stretch of the river Godavari, the total riverine ecological system of Godavari from Gangapur Dam to pitchavaram mangrove wet land in the Bay of Bengal got highly affected. Necessary changes in the releasement for environmental flow can be effected quickly enough to sustain the river ecosystem before irreversible damage is done to the catchment and water resources.

CHAPTER 3

METHODOLOGY FOR DISSERTATION WORK

3.1 GENERAL

It is an accepted fact that water is the most important natural resource without which life on earth will not exist. Some anaerobic bacteria can live without oxygen but not without water. The role of water as a life sustainer has been taken for granted by human beings. It was not until the 1960s that consciousness concerning the water quality and not only water quantity has started in the mind of the public [1].

One way to express the quality of water is by listing out the concentrations of everything that the water contains. This list will be as long as the number of constituents analyzed and can be anything from twenty common constituents to hundreds. Comparing the quality of different samples of water is thus, almost an impossible task. For example, a sample of water having six parameters – pH, hardness, chloride, sulphate, iron and sodium – 5% above the permissible limits may not be as bad for drinking as another sample with just one constituent – e.g. mercury– at 5% higher than permissible [1].

The quest for determining the quality of water has led to the collection of a large volume of data in the past four to five decades. With the development of technology, this volume of data has been increasing at a very fast pace and it is challenging man's ability to understand and assimilate it [24]. This vast volume of data has to be analyzed and presented in such a way that everyone from the policy and decision makers and layman can understand it. Water quality data is very difficult to present in a simple way but the concept of "water quality index" has been found as the easiest way of expressing it.

An index is a means devised to reduce a large quantity of data down to its simplest form, retaining essential meaning for the questions being asked of the data. In short, an index is designed 'to simplify' [24]. It is a number that is created by mathematically combining a set of numbers. It does not represent a particular measurement, but it can be used to make comparisons simpler. A water quality index (WQI) combines several different water quality parameters. The parameters used to develop a WQI are picked up based on the historical information, ecological importance, human use, seasonal fluctuations, and other considerations [10]. In the process of simplification, some information is lost. However, if designed properly, the lost information will not seriously distort the true picture [24].

Water quality indices are generally of two forms:

i) Those in which the index numbers increase with increasing pollution, and

ii) Those in which the index numbers decrease with increasing pollution.

Some specialists in the field refer to the former as "environmental pollution" indices and the latter as "environmental quality" indices. However, these terms are not universally accepted. The general terms for these indices are either "increasing scale" form, in which the index values increase with increasing pollution, or "decreasing scale" form, in which the index values decrease with increasing pollution [24].

A versatile WQI generally should satisfy the following conditions:

i. The value of the index changes with changes in the values of each of the water quality variables,
ii. The changes in the value of an index should be more significant due to a variable which produces more significant impact to the water quality,
iii. The value of an index should approach the poorest designated value when a critical variable, whose concentration beyond the permissible levels cannot be compromised, exceeds the permissible limits, and
iv. The value of an index should remain unchanged when a variable's concentration changes within its permissible limits [1].

Public awareness and consciousness about pollution in general and pollution of water in particular has increased over the recent years. Emergences of International Organization like Green Peace are testimony to this fact. However, in spite of awareness of water quality and water pollution, the general public is at loss to understand the actual level of water quality as it is explained in technical parameters. In such circumstances, if the water quality is expressed in terms of numbers, the public as well as technologists and administrators can better understand it.

An index is a mean device to reduce a large quantity of data down to a simplest form. First the term environmental indicator or sub-index function is calculated which refers to a single quantity derived from one or two polluted variables/characteristic parameters (Ott-1978). It is used to reflect some environmental attribute. Water Quality Index (WQI) is then calculated by a mathematical aggregation of two or more indicators in some fashion. It is simply a numerical value having no units. WQI is a comparison of water quality or status to a prescribed base or to a scientific arbitrary standard. Various ranges of 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 etc.

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 Godavari River has been monitored conventionally for all seasons. Ten sampling stations are selected after conducting the reconnaissance survey of the river. Samples were collected in December and February and analysed for the required parameters for primary data also secondary data collected for the period January 2002 to December 2007 from CPCB and MPCB Websites.

The Central Pollution Control Board (CPCB) has established a network of monitoring stations on rivers across the country. The present network comprises of 870 stations in 26 states and 5 union Territories spread over the country. The monitoring is done on monthly or quarterly basis in surface waters and on half yearly basis in case of ground waters. The water quality data are reported in water quality status year book. The water quality data on all the monitoring locations is computed for the year 2004 and is summarized as minimum, maximum and mean value for all the rivers in a basin. The monitoring locations are arranged according to the longitudinal profile of the river from its origin to its confluence with the deeper valley of the larger river or before meeting to the sea.

The Central and State Pollution Control Boards/ Pollution Control Committees in Union-Territories in India are responsible for restoration and maintenance of the wholesomeness of aquatic resources. To ensure that the water quality is being maintained or restored at desired level it is important that the pollution control boards regularly monitor the water quality. The water quality monitoring is performed with following main objectives.

i. For rational planning of pollution control strategies and their prioritization;
ii. To assess nature and extent of pollution control needed in different water bodies or their part;
iii. To evaluate effectiveness of pollution control measures already is existence;
iv. To evaluate water quality trend over a period of time;
v. To assess assimilative capacity of a water body thereby reducing cost on pollution control;
vi. To understand the environmental fate of different pollutants.
vii. To assess the fitness of water for different uses.

3.1.1 Water Quality Assessment and Management:

The objective of water quality management is to control the discharge of pollutants so that water quality is not degraded to an unacceptable extent below the natural background level. However controlling waste discharges must be quantitative endeavors. We must be able to measure the pollutants, predict the impact of the pollutant on water quality, determine the background water quality which would be present without human invention and decide the levels acceptable for intended uses of the water.

Pollution is the introduction of any substances or energy (chemicals, noise, heat, light, energy and others) into the environment which results in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems, and impair or interfere with amenities and other legitimate uses of the environment. The simplest definition of water pollution is "the loss of any of the actual or potential beneficial uses of water caused by any change in its composition due to human activity".

Rivers are the surface water bodies characterized by the unidirectional current with a high average flow velocity (ranging from 0.1 to 1 m/s). The flow is highly variable in time depending on the climatic situation and drainage pattern. Through and continuous vertical mixing is achieved due to prevailing current and turbulence. They transport sediment from continental highlands to lakes, alluvial fans, and ultimately the ocean.Towns and factories are built near rivers so that they can use water from the river. But often the water is not cleaned before it is put back into the river. This dirtying of river water (also air and soil) is called river pollution.

India's fourteen major, 55 minor and several hundred small rivers receive millions of liters of sewage, industrial and agricultural wastes. Most of these rivers have been degraded to sewage flowing drains. There are serious water quality problems in the towns and villages using these rivers as a source of their water.
It means the assessment of water quality & thereby to define the pollution status of a particular river for a particular stretch or for the whole stream along with its all tributaries, if necessary in the basin area of the identified or suspected location.

Generally both quantitative and qualitative assessment of the pollutants at the outfalls, river water at upstream and downstream monitoring stations as well as sediment is carried out to depict the pollution profile of that river. Several factors are to be considered such as pollution load, river discharge, mixing nature, carrying capacity, sampling techniques and the method of quantification. Results are generally expressed in the form of table, graph or indices.

Information required studying the pollution profile of a river:
Physical characteristics: Topography, Catchment Area, Annual flow rate, Type of flow, Seasonal variation:
Pollutant's characteristics: Type of pollutants:

Table 3.1: Classification of major water pollutants:

Sl No	Types	Examples
1	Oxygen demanding wastes	Human & animal waste, decaying vegetation.
2	Plants nutrients	Nitrates & phosphates.
3	Infectious agents	Bacteria, virus, protozoa, fungi.
4	Organic matters	Oil, detergents, pesticides etc.
5	Inorganic metals & chemicals	Acids, Heavy & toxic metals
6	Priority pollutants	DDT(organo chlorine),PCBs(polychlorinated biphenyl), POPs (dioxin & furan).
7	Heat	Used water for cooling in industries.
8	Radioactive substances	Fallout products, radioactive wastes.

Parameters to be analyzed:

Analyses of the following water quality parameters, not all of them at a time, are to be carried out in order to detect pollution of a river. Samples are to be collected from the drainage outfall point, river water as well as from the sediments of the river.

1. Physical parameters like PH, Temperature (^{0}C),Turbidity (NTU), TSS (mg/l), TDS(mg/l),Color, taste & odour, Electrical conductivity (μ-mho/cm), Radioactivity etc.
2. Chemical parameters like BOD, COD, DO (mg/l), Ca, Mg as CaCO3, Oil & grease (mg/l), Sulphates, Chlorides etc.

3. Biological parameters like Total coliform (MPN/100ml), Faecal coliform (MPN/100ml)

3.2 RECONNAISSANCE SURVEY

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

a. The industrial effluents are confluences with the Godavari River water.
b. The domestic waste water is directly discharging into the river.
c. Two crematoria's are used on the bank of Godavari River
d. The waste water including urine, sewage, bio-medical waste and solid wastes of the Nasik city are directly discharging into the river..
e. River water is being utilized for agricultural purposes at Nasik corporation area.

3.2.1 Measurement of Godavari River Water Quality:

In practice, sampling programmes designed to monitor physico-chemical characteristics are carried out at frequencies between weekly and monthly. It is advisable, however, that such regular sampling be augmented by more detailed surveys, e.g. of 24-hour duration, carried out in the more important reaches at critical periods. The most important period is likely to be in the summer or autumn months when river flows are at their maximum, water temperatures are at their maximum and dissolved oxygen levels are at their lowest.

3.2.2 Present Approach to Water Quality Management:-

The water quality management in India is performed under the provision of Water (Prevention and Control of Pollution) Act, 1974. The basic objective of this Act is to maintain and restore the wholesomeness of national aquatic resources by prevention and control of pollution. The Act does not define the level of wholesomeness to be maintained or restored in different water bodies of the country. The Central Pollution Control Board (CPCB) has tired to define the wholesomeness in terms of protection of human uses, and thus, taken human uses of water as base for identification of water quality objectives for different water bodies in the country. It was considered ambitious to maintain or restore all natural water bodies at pristine level. Planning pollution control activities to attain such a goal is bound to be deterrent to development activities and cost prohibitive. Since the natural water bodies have got to be used for various competing as well as conflicting demands, the objective is aimed at restoring and/or maintaining natural water bodies or their parts to such a quality as needed for their best uses. Thus, a concept of "designated best use" (DBU) was developed. According to this concept, out of several uses a water body is put to, the use which demands highest quality of water is termed as "designated best use", and accordingly the water body is designated. Primary water quality criteria for different uses have been identified. A summary of the use based classification system is presented in table 1.4

3.2.3 CPCB Annual Report of Environmental Monitoring:-

Water quality monitoring is an important exercise, which helps in evaluating the nature and extent of pollution control required, and effectiveness of pollution control measures already in existence. It also helps in drawing the water quality trends and prioritizing pollution control efforts. CPCB identifies areas of high priority based on the severity of the problem. These water bodies are not meeting the desired level of water quality for defined use with respect to Bio-chemical oxygen demand. In the present analysis, those water bodies having BOD more than 6mg/l are identified as polluted water bodies. In some of the states few surface water bodies are identified as that they are having polluted stretches. The SPCB were requested to take remedial measures and formulate action plans to restore the water quality of the water bodies by CPCB.The government of India has taken so many steps to control pollution through various legislations, Water Act, Environmental protection Act and Action plans such as Ganga action Plan, Yamuna action Plan and other river action plans. Even then the pollution of rivers and the water quality in the rivers has not yet improved to the expected level. The reasons are the lack of public participation in planning, execution and post implementation stages. The various stakeholders were not involved in planning, selection of technology and decision making processes.

3.2.4 National Water Quality Management Strategy:-

The National Water Quality Management Strategy (NWQMS) has been jointly developed since 1992 by the Australian Government in cooperation with state and territory governments, currently under the Natural Resource Management Ministerial Council. Other ministerial councils have also been involved for some issues. The NWQMS is part of the Council of Australian Governments' (COAG) Water Reform Framework and is acknowledged in the National Water Initiative.

Policies

The main policy objective of the NWQMS is to achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development.

Process

The NWQMS process involves community and government development and implementation of a management plan for each catchment, aquifer, estuary, coastal water or other water body. This includes use of high-status national guidelines with local implementation.

National guidelines

Following are the major NWQMS guidelines for managing key elements of the water cycle.

The NWQMS guidelines cover:

a. policies and processes to achieve water quality
b. effluent and sewerage system management
c. urban storm water and recycled water
d. fresh and marine water quality
e. monitoring and reporting
f. groundwater protection
g. drinking water
h. guidelines for diffuse and point sources.

3.3 WATER QUALITY INDICES

The indices will help us to reduce the large amount of water quality data into simple numbers which can easily be interpreted and understood. Index values, thus, calculated can be mapped to show the water quality in the river. The index values can also form the basis for making decisions on the type and extent of conservation measures to be taken to restore the river back to its original condition.

3.3.1 Historical Development

The concept of using indices to represent in a single value the status of several variables is not a novel idea. It has been a common method in economics and commerce for a very long time now, e.g. the 'consumer price index' is a single value obtained on the basis of an integration of the prices of certain commodities in order to determine whether the market is, overall, cheaper or costlier at any given instant compared to any other past instant. Similarly, a WQI gives a single value to the water quality of a source by integrating the concentrations of its constituents. In this way, one can easily compare the quality of different sources of water [1].

Water quality indices have gained popularity during the last three decades. This concept, in its very rudimentary form, was first introduced in Germany way back in 1848 when the presence or absence of certain biological organisms in water was used as an indicator of its level of purity or pollution. Since then, several European countries have developed and applied different systems to classify the quality of the water within their boundaries. These water classification systems usually were of two types:

i) Those concerned with the amount of pollution present, and

ii) Those concerned with living communities of macro- and microscopic organisms.

Rather than assigning a numerical value to represent water quality, these classification systems categorized water bodies into one of several pollution classes or levels. By contrast, indices using a numerical scale to represent gradations in water quality levels is a recent phenomenon, beginning with Horton's index in 1965 [24].

3.3.2 Significance / Uses of Water Quality Indices

It has been emphasized by agencies responsible for water supply and control of water pollution that it is desirable to develop and utilize water quality indices, as the role played by these indices is usually linked to the basic reason for which environmental monitoring data are collected. Indices play a role in evaluating the effectiveness of regulatory activities and in translating the complex data into a form that is easily understood. The indices serve as convenient tools to examine trends, to highlight specific environmental conditions, and to help governmental decision-makers in evaluating the effectiveness of regulatory programme [1].

A report by the Planning Committee on Environmental Indices of the National Academy of Sciences (NAS), United States of America (1975) indicated that the indices play an important role in four ways:

i) To assist in formulating policy;
ii) To provide a means for judging the effectiveness of environmental protection programmes;
iii) To assist in designing these programmes; and
iv) To facilitate communications with the public concerning conditions of the environment and progress towards its enhancement [24].

Wayne Ott [24] identifies six basic uses of indices:

a. Resource allocation Indices may be applied to water related decisions to assist managers in allocating funds and determining priorities.
b. Ranking of Locations Indices may be applied to assist in comparing water quality at different locations or geographical areas.
c. Enforcement of standards Indices may be applied to specific locations to determine the extent to which legislative standards and existing criteria are being met or exceeded.
d. Trend Analysis Indices may be applied to water quality data at different points in time to determine the changes in the quality (degradation or improvement) which have occurred over the period.

e. Public Information Indices may be used to keep the public informed about the overall water quality of any source, or of different alternative sources, on a day-to-day basis.

f. Scientific Research Indices may be used to reduce a large quantity of complex water quality data to a simple form which makes their application very valuable in scientific research.

The development of water quality indices remains quite a controversial issue with the primary debate centering on the amount of information which is lost in the process of simplification from a huge quantity of data to a simple number. One view holds that the raw, undoctored data give the best means of evaluating water quality and the distortions caused by index development are unacceptable. This view is usually held by those involved with water quality measurements. On the contrary, persons not involved in water quality measurement are more willing to accept the distortion for the reason that indices give a simplified picture of the water quality of a source. This argument illustrates the "classic dichotomy" of views towards all types of environmental indices.

3.3.3 Development of Indices

The calculation of an index consists of the following fundamental steps:

i) Selection of pollutant variables or parameters,

ii) Transformation of the pollutant variables with different units and dimensions to a common scale by calculating the sub-indices for each variable,

iii) Assignment of weightages to the different pollutant variables, and

iv) Aggregation of the sub-indices into the overall index.

Selecting pollutant variables for an index is a very difficult job. From among the hundreds of variables a water sample can have, one has to choose only a set of a few variables which together will reflect the overall water quality for the given end use. It is here that subjectivity creeps in as different experts and end users may have different perceptions of the importance of a variable vis-à-vis a given end use. This step in index development is as fraught with uncertainty and subjectivity as it is crucial to the usefulness of the index. Hence, enormous care, attention, experience and consensus-gathering skills are required to ensure that only the most representative variables are included in a particular index. It may consist of a simple multiplier, or the pollutant variable raised to a power, or some other functional relationship.

Selecting weightages for the different pollutant variables is another step which is a matter of personal opinion; hence, subjectivity again creeps in. In some indices, equal weightage is given to all the variables. But in a majority of indices, different weightages are assigned to different variables. For this step, well formulated techniques of opinion gathering such as the Delphi Method are utilized to minimize subjectivity and enhance credibility. Once the sub indices are calculated, these are usually aggregated together in a second mathematical step to form the final index, The aggregation function usually consist either of a summation operation, in which individual sub indices are added together, or a multiplication operation, in which a product is formed of some or all of the sub indices, or a maximum operation, in which just the maximum sub index is reported.

3.3.4 Classification of Water Quality Indices

There are two general types of water quality index forms.

a. Increasing scale form – those in which the index numbers increase with increasing pollution level.
b. Decreasing scale form – those in which the index numbers decrease with increasing pollution level.

Some specialists in the field refer to the former as "Water Pollution Indices" and later as "Water Quality Indices". In an increasing scale form, an index of zero indicates no pollution, while, in a decreasing scale form, index of zero indicates maximum polluted or 100% polluted water. Both the terms are inter-related and, therefore, in practice both type of indices are called "Water Quality Indices".

To present many indices found in the literature in an orderly fashion, Wayne Ott (1978) [24] has classified the different water quality indices developed into four general categories:

i. General water quality indices,

ii. Specific-use indices,
iii. Planning indices, and
iv. Indices based on statistical approach.

General conditions to be satisfied by WQI

a. It should change with the changes in the values of each of the water quality variables.
b. The change should be greater due to a variable, which produces the more important quality impact.
c. It should approach the poorest designated value when a critical variable, whose concentration beyond the permissible levels cannot be compromised, exceeds the permissible limits.
d. It should remain unchanged when a variable's concentration changes within its permissible limits.

Criteria for formulation of WQI as given by Council of Environmental Quality (CEQ) are:

It should facilitate communication of environmental quality information to the public.

It should be readily derived from available monitored data. It should strike a balance between over simplification and complex technical conceptualization. It should impart an understanding of significance of data represented. It should be objectively designed but amenable to comparison with expert judgment so that their validity can be assed.

3.3.4.1 General water quality indices

Water has a variety of different uses, viz. public drinking water supply, irrigation, recreational etc. Water quality requirements vary depending upon the intended use. Some indices, however, are based on the assumption that "water quality" is a general attribute of surface water irrespective of the use to which the water is put. Such indices are termed as general water quality indices which include different WQIs. Some selected WQIs are discussed below.

a. **Horton's Quality Index:** Horton's index was the first formal water quality index which was introduced in 1965 [24]. Horton selected eight of the most commonly measured water quality variables for his index and fixed weights ranging from 1 to 4 for each variable (Table 3.1). Among the variables, specific conductance served as an approximate measure of total dissolved solids (TDS) and carbon chloroform extract (CCE) reflected the influence of organic matter. A major drawback of Horton's index was that it did not include the effects of toxic substances.

Horton (1965) proposed first water quality index formulated on the following criterion

- Number of variables should be limited
- Variables should be of significance
- Variables should reflect the availability of data.

b. **National Sanitation Foundation water quality index (NSFWQI):** This water quality index is selected for present study because of its versatility and also on line software available on internet for calculating indices, hence studied and explained in detail in 3.2.5

c. **Prati's Implicit Index of Pollution:** Prati et al. (1971) proposed an index for surface water based on the water quality classification system given as under. They considered 13 pollutant variables.

$$PIIP = \frac{1}{n}\sum_{i=1}^{n} q_i$$

This index was developed by Prati, Pavanello and Pesarin [24] in 1971 on the basis of water quality standards used in a number of countries. The concentration values of all the pollutants were transformed into levels of pollution expressed in new units through mathematical expressions. These mathematical expressions were constructed in such a way that the new units were proportional to the polluting effect relative to other factors. It should be noted that toxic substances were not included in the index as it was felt that in case a toxic substance is present in concentrations above a given limit, the index is automatically classified in the highest category, i.e. heavily polluted.

d. **McDuffie's River Pollution Index:** McDuffie et al. (1973) presented a WQI, which they called the River Pollution Index (RPI). Although 8 pollutant variables are discussed in their paper, either fewer or more than 8 variables can be included depending on the available data.

e. Dinius' Social Accounting System: Dinius (1972) proposed a water quality index as a first step towards designing a 'rudimentary social accounting system', which would measure the costs and impact of pollution control efforts. This WQI includes 11 parameters. Like Horton's index and NSF WQI, it has a decreasing scale with values ranging from 0-100.

f. Oregon Water Quality Index: The Oregon Water Quality Index (OWQI) was introduced in the 1970s and was improved in 1995 to reflect the advances in the knowledge of water quality and in the design of water quality indices. It is a single number that expresses the quality of river water by integrating the measurements of eight water quality variables, viz. temperature, dissolved oxygen, biochemical oxygen demand, pH, ammonia+nitrate nitrogen, total phosphorus, total solids and faecal coliform [10]. It aids in the assessment of water quality for general recreational uses (i.e. fishing and swimming). The original OWQI was modeled after the National Sanitation Foundation's Water Quality Index (NSFWQI).

g. Said, Stevens and Sehlke Water Quality Index: The Said, *et al* Water Quality Index (WQI) [26] was developed with a view to have an index which uses fewer water quality variables and which can be used to compare sites having different water quality. This WQI was constructed using only the basic water quality variables, which include dissolved oxygen (DO), faecal coliform, turbidity, total phosphorus and specific conductance. The other variables that affect the water quality, such as pH, temperature, and nitrogen are reflected to a certain degree by these basic variables. This index is further simplified by the fact that the step for calculating subindices has been eliminated. The index was designed to range from 0 to 3. The maximum or ideal value of this index is 3 and is possible in very good waters that have 100% dissolved oxygen, no TP, no faecal coliform, turbidity less than 1 NTU, and specific conductance less than 5 μS/cm. From 3 to 2, the water is acceptable and values less than 2 mean that the water is marginal and some remediation processes are needed. If one or two variables have deteriorated, the value of this index will be less than 2. If most of the variables have deteriorated, the index is less than 1, which means that water quality is poor.

3.3.4.2 Specific Use Indices

Indices developed in consideration of the specific use of water are classified as per specific use indices. These are indices designed for specific water use and include indices such as O'Connor's Indices designed for public water supply, Deininger and Landwehr's Public Water Supply Index, Walski and Parker's Index designed for recreation, Stoner's Index designed for public water supply and irrigation, etc.

a. **O'Connor's Indices***:* O'Connor developed two water quality indices for specific, but very different, water uses. His first index was the Fish and Wildlife (FAWL) index and it was intended to describe the quality of a surface body of raw water used to sustain a population of fish and wildlife. His second index was the Public Water Supply (PWS) index which was intended to describe the quality of a surface body of raw water which will be treated as necessary and used for public water supplies. Both indices were developed using Delphi technique to reduce the subjectivity in selection of the pollutant variables and their weights.

b. **Walski and Parker's Index***:* Walski and Parker introduced this index in 1974. It was based on empirical information on the suitability of water for a particular use, and was developed specifically for the recreational water, such as swimming and fishing. The authors introduced four general categories of variables:

(1) Those which affect aquatic life (e.g. DO, pH, and temperature),

(2) Those which affect health (e.g. coliforms),

(3) Those which affect taste and odour (e.g. threshold odour number); and

(4) Those which affect the appearance of the water (e.g. turbidity, grease and colour).

c. **Stoner's Index***:* Stoner proposed an index designed for use in public water supply and irrigation. This index employed a single aggregation function which selected from two sets of recommended limits and subindex equations. This approach was viewed as a general structure designed to accommodate any water use. Although Stoner applied the index to just two water uses, it could be adapted to additional water uses as well.

3.3.4.3 Planning indices

These indices are designed specifically for management decision-making and they do not usually depict ambient water quality or related conditions. Instead, they are "custom-designed" to assist the user in making specific decisions or in solving particular problems. Planning indices often incorporate variables other than those routinely measured by water pollution monitoring programmes. For example, a planning index designed for allocating water pollution abatement funds might include the "cost of wastewater treatment facilities". Some of such indices are MITRE's National Planning Priorities Index (NPPI), Dee's Environmental Evaluation System, Inhaber's Canadian National Index, Johanson and Johnson's Pollution Index, etc.

a. **MITRE's National Planning Priorities Index (NPPI):** It was designed as a tool for assigning priorities to different demand sectors in order to ensure that funds are granted and used in a cost-effective manner for the planned water treatment projects. Each sub index was calculated using a segmented linear function and the final index was computed as the weighted sum of 10 sub indices:

b. **Dee's Environmental Evaluation System***:* Dee *et al* proposed a system for evaluating the environmental impact of large scale water resources projects. The system included a water quality index, which was represented by 12 common water quality variables (such as DO pH, turbidity and faecal coliforms), besides pesticides and toxic substances. The sub indices of various water quality variables were similar to those in the NSFWQI. The index was calculated with and without considering the proposed water resources project. The difference between the two scores provided a measure of the environmental impact (EI) of the project:

c. **Inhaber's Canadian National Index***:* The Environmental Quality Index was suggested by Inhaber in 1974 as a national index for Canada. It included an air quality index, a water quality index, and a land quality index. The water quality index combined two sub indices in a root mean square operation – an ambient water quality sub index and a pollutant source sub index based on effluents from point sources. The pollutant source sub index was based on pollutant variables measured in effluents from five sources, viz.

municipal wastes, the petroleum-refining, chlor-alkali, fish-processing and paper industries. The sub indices were combined in successive root mean square operations.

d. **Johanson and Johnson's Pollution Index***:* Johanson and Johnson (1976) developed a planning index as a tool to assist in the process of identifying locations of in-place pollutants, particularly toxic pollutants, in harbours and navigable waterways and to take steps to remove and dispose of them. They used the index to screen 652 data sets from waterways across the United States of America. For each pollutant i, the weight was based on the reciprocal of the median of observed national concentrations. Using the index, it was possible to scan the data by computer and identify the locations receiving the highest priority for removal of pollutants.

3.3.4.4 Indices based on statistical approach

These indices usually employ some standard statistical procedure, already available in literature, adapted for use with water quality data. The statistical approaches have the advantage that they incorporate fewer subjective assumptions than the traditional indices. However, they are more complex and often more difficult to apply. Harkin's Index is an example of this type of indices. One more type of water quality index does exist in literature, i.e. "Biological Water Quality Indices". These are generally developed after evaluating water quality in terms of its impact on aquatic life in some form. The biological indices are entirely dissimilar in approach to other categories.

a. **Harkin's Index***:* Harkin presented a statistical approach for analyzing water quality data based on the rank order of observations. It begins with ranking the observations for each pollutant variable, including a control value, which is usually a water quality standard or recommended limit.

3.3.5 INDICES SELECTED FOR DETERMINING THE WATER QUALITY OF THE STUDY STRETCH OF GODAVATI RIVER:

National Sanitation Foundation's Water Quality Index selected for studying the water quality of the River Godavari. With the river being visibly much polluted, no specific uses were possible with its water. Hence, an only general water quality index is selected.

Sufficient literature was available explaining how to calculate indices. The NSFWQI was selected because it was the most widely used water quality index in the world. It had been field tested in different river basins all over the world and it had proven its applicability. The colour scheme suggested by Brown *et al* for representing the index, made interpretation and understanding of the water quality at different points along the river very easy. Also online software available on internet for to calculate water quality index easily. 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. Considering the evaluation of water quality index of the Godvari River, the National Sanitation Foundation Water Quality Index (NSF WQI) applied to evaluate the water quality.

This WQI is selected because other indices are having various limitations like,

i. They can only be used to assess water quality for general uses.
ii. They cannot be used in making regulatory decisions or to indicate water quality for specific uses.
iii. They cannot always show the impact of random short-term changes, such as a spill, except if it occurs repeatedly or for a long time. The best results with this index can be obtained only in natural conditions and natural measurement sites (not downstream of river outfall).
iv. Localized changes in water quality are not immediately reflected.
v. Changes in the stream habitat are not reflected by this index.
vi. The index cannot be used to indicate contamination from trace metals, organic contaminants or other toxic substances.
vii. Some index has also not considered the effects of biochemical oxygen demand which is a very important pollutant variable.

3.3.6 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.

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

The weights for 9 parameters are given in the Table 3.2

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 indicates better water quality of the river.

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

a. It should facilitate communication of environmental quality information to the public.
b. It would be readily derived from available monitoring data.
c. It should strike a balance between over simplification and complex technical conceptualization.
d. It should impart an understanding of significance of data represented.
e. It would be objectively designed but amenable to comparison with expert judgment 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 indicates higher value of the index is to be better water quality.

The water quality index of the Godavari River at the various sampling stations has been calculated by the NSFWQI through Online software available on internet at www.water-research.net/watrqualindex by Wilkes University, Center for Environmental Quality, environmental Engineering and Earth Sciences, Wilkes-Barre, PA as follows.
Brown et al. (1970) presented a water quality index similar in structure to Horton's index. A decreasing scale, 0 – 100 is used for expressing the water quality index. It is also called National Sanitation water Quality Index. A system of reporting NSFWQI which relates

the index values to 5 descriptors words and colours was also suggested by Mechelland et al. (1976) as shown in the following Table 3.2

Table 3.2: 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

Source: [24]

In this form if any one sub-index approaches zero, the over all index approaches zero. A system of reporting NSF WQI which relates the index values to 5 words and colours was also suggested by MeClelland et al. (1976) as shown in Table 3.3

In 1970, Brown, McClelland, Deininger and Tozer [24] presented a water quality index supported by the National Sanitation Foundation, United States of America. This index came to be popularly known as the National Sanitation Foundation's Water Quality Index (NSFWQI). It was developed using a formal procedure based on the Rand Corporation's Delphi Technique combining the opinions of a large number of water quality experts of the U.S.A. In this approach, the experts were given a questionnaire and their opinions were tabulated and reported to each member. This enabled the members to see and compare his response vis-à-vis that of the others. The experts were given two more sets of questionnaires and were asked to prepare rating curves to finally arrive at a consensus on the index. After analysis of all the questionnaires, the investigators identified 9 individual variables and 2 grouped variables of greatest importance. The individual variables were DO, faecal coliforms, pH, BOD, nitrates, phosphates, temperature, turbidity and total solids. The grouped variables were toxic substances and pesticides.As for the two grouped variables, it was unanimously agreed by all panelists that for pesticides, the NSFWQI would automatically be set to zero if the concentration of detectable pesticides (of all types) exceeds 0.1 mg/L and for toxic substances and it would be set to zero if any toxic substance exceeded its assigned upper limit, as prescribed in published drinking water standards.

The next step was to derive a set of weights which would sum to 1.0 but which would reflect the significance ratings assigned to the variables by the panelists. The arithmetic means of the significance ratings were calculated for all variables rated (Table 3.2). "Temporary weights" were then derived by dividing the variable with the highest significance rating, i.e. DO which is 1.4, by the significance rating of each variable. Finally, each temporary weight was divided by the sum of the temporary weights to give the sub index weights (last column of Table 3.2). The temperature pollutant variable is defined as the deviation from equilibrium temperature (degrees Celsius). Equilibrium temperature is that which occurs without the influence of a heated or cooled discharge. In field applications, two temperatures are taken: one at the sampling site and one at some point upstream where a heated or cooled discharge is known to be absent. To calculate the index, one has to read the sub index value I_i from the appropriate curve for the pollutant variable i_n. The sub indices are then multiplied by the weighting factor to arrive at a subtotal for each variable. The nine resulting subtotals are then added using a weighted linear summation:

Finally, the developers of the NSFWQI also suggested a way of reporting the index. This reporting procedure relates the index values to five descriptor words and to colours of the spectrum as shown in Table 3.3 below.

Table 3.3: Descriptor Words and Colours Suggested For Reporting the NSFWQI

S.No.	Descriptor Words	Numerical Range	Colour
1	Very Bad	0- 25	Red
2	Bad	26- 50	Orange
3	Medium	51- 70	Yellow
4	Good	71- 90	Green
5	Excellent	91-100	Blue

Source [24]

The NSFWQI is the most widely used of all existing water quality indices. It has been field-tested and applied to data from a number of different geographical areas and has withstood the tests. It is an effective technique for reporting water quality data, examining trends and evaluating the effectiveness of water pollution control programmes. Another advantage of the NSFWQI is that if data of all the 9 variables are not available, the overall WQI can still be estimated by adding the results and then adjusting for the number of pollutant variables with available data. For example, if there are 2 variables with no available data, the 7 remaining subtotals are added and the 7 weighting factors are added. The former is then divided by the latter to obtain the final WQI [49].

The main limitation of the additive form of the NSFWQI is eclipsing of the result when a single pollutant variable shows extremely poor water quality. This has been overcome by using the multiplicative form, which is equivalent to the weighted product aggregate with the same weights becoming powers of the sub indices.

CHAPTER 4

WATER QUALITY ASSESSMENT OF STUDY STRETCH OF GODAVARI RIVER

4.1. General

Indiscriminate disposal of sewage and industrial waste in rivers has led to serious river pollution in India. Effective monitoring of quality parameters is an important initial step in abatement of river pollution. Monitoring of water quality through physical senses, general appearance, taste and odour, is a very old practice. Modern monitoring techniques could be classified as conventional, automatic recording and remote sensing techniques. In present study, river Godavari was monitored conventionally (i.e. samples were collected manually) for three months. After conducting reconnaissance survey, eight sampling stations (river point) were chosen. Water samples were collected from these sampling stations in the month of December 2007 and February 2008, transported to laboratory and tested for various water quality parameters at Environmental Laboratory of Maharashtra Pollution Control Board and Om Laboratory Nasik.

For the convenient of discussion, the methodology has been divided into two parts:

(I) Methodology for water sample collection and analysis

(II) Methodology for Calculation of NSF Water Quality Index

Reconnaissance Survey

The sampling schedule, locations and frequency of sampling was decided after the reconnaissance survey was made. Data pertaining to the catchment activities, significant from the view of having an impact on river system, was collected from Nasik City and nearby areas. During reconnaissance survey, a preliminary strategy was made about the sampling programme to carryout the study in a convenient manner according to available resources.

Criteria for Selection of Sampling Station

The sampling station should be located to provide a 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 depending 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.

13 To see that the secondary data is available, that's why the sampling locations are selected on the basis that those points are having the available secondary data.

Based on the above criteria, ten numbers of sampling stations were identified along the stretch of the Godavari River and the outfall of small industrial nalla near someswar and other industrial units along with sewage water of Satpur and Ambad MIDC, Residential areas and Ramkund area including before and after confluencing with the Kapila River to Godavari River.

4.2 SELECTION AND DESCRIPTION OF SAMPLING STATIONS

Ten sampling locations were selected along the River Godavari at Nasik city as per para 4.1.2. The objective of sampling is to collect the water samples form the river at the various point sources. The following sampling stations of the Godavari River are selected on the basis of required criteria. For the present study, only two months primary/fresh water quality data was generated. The other secondary data used has been taken from a report on a joint study, conducted by the Nasik Municipal Corporation and the Maharashtra State Pollution Control Board (MPCB),. The data taken from this report has been used in the calculation of all the NSF water quality indices chosen. Also secondary data taken from CPCB and MPCB websites. The methodologies adopted for sampling and description of the sampling locations are as follows.For assessment of water quality of River Godavari ten locations were selected. The general layouts of the sampling stations are shown in enclosed maps and locations of sampling stations are given in Table 5.2. The study covers about 65 km stretch of river starting from Kushawart Trimbakeswar to Saikheda Village.

The details of these sampling stations are given as below.

Table 4.1 Location of sampling stations

Sr. No	Category	Sampling station	Location
1	River Point	S_0	Kushawart
2	River Point	S_1	Gangapur Dam
3	River Point	S_2	Someswar
4	River Point	S_3	Anandwali
5	River Point	S_4	Victoria Bridge
6	River Point	S_5	Ramkund

7	River Point	S_6	Goda Kapila Sangam
8	River Point	S_7	Tapowan, D/s Nasik
9	River Point	S_8	Dasak Village
10	River Point	S_9	Saikheda Village

The detailed descriptions of above sampling stations are given as follows.

1 **Sampling station (SS_0): Kushawart:** This sampling station is selected at the source of the Godavari River; water comes from origin of the river before confluencing with the Kushawart pond. The Godavari River is not received any effluent or sewage before this station. This sampling location is ten kilometers from origin of the river Godavari.This sampling station is selected because it represents the clear water zone before water enters in to the kushawart bathing pond, and mass bathing activities are observed at this point. In this area, no pollution activities are their like remarkable industries or motor workshops are situated. Origin of river is assumed as reference point, from where the river starts and designated as Class A of water quality.

2 **Sampling station (SS_1): Gangapur Dam:** This sampling station is located at the Gangapur Village and about 28 km away from the source of the Godavari River. This sampling station is selected and recognized by the pollution control board, only water storage activity is their at this point. This is the main drinking water source for Nasik City, water used for drinking purpose after disinfection.

3 **Sampling station (SS_2): Someshwar:** The sampling station is located at someswar at a distance of 6 km from the previous sampling station SS_1 and total distance of about 34 km from the source of the Godavari River. Bathing and Cloth washing activities are observed at this point. Also pooja materials are disposed in the river.

4 **Sampling station (SS_3): Anandwali:** The sampling station is located at Anandwali village at a distance of 5 km away from the SS_2 and about total distance of 39 km from the source of the Godavari River. The sewage water from the Anandwali village area confluenced with the water of the Godavari 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 washing activities of animals, cloth, vehicles, hotel, restaurant, pathological laboratories, nursing homes etc in this area and ultimately reached to the Godavari River.

5 **Sampling station (SS_4): Victoria Bridge:** This sampling station is located in the heart of the city which is near ramkund, at a distance of 3 km from the previous sampling station SS_3 and at about total distance of 42 km from the source. The sewage water from the some residential areas is confluenced with the Godavari River water.

6. **Sampling station (SS_5): Ramkund:** This sampling station is located in city area which is at a distance of 1 km from the SS_4 and at about total distance of 43 km from the source of the Godavari River. Mass Bathing activities are observed at this point.

7 **Sampling station (SS_6): Goda Kapila Sangam:** This sampling station is located at the down stream of the Nasik city area which is about 2 km away from the SS_5 and at a total distance of about 45 km from the source of the Godavari River. Kapila river water is mixed at this point; besides this the sewage water is also released from the washing activities of animals, cloth, vehicles, hotel, restaurant, pathological laboratories, nursing homes etc in this area and ultimately reached to the Godavari River.

8 **Sampling Station (SS_7): Tapowan or Down stream of Nashik** :This station is located at Tapowan area which is at a distance of about 1 km from the SS_6 and at a total distance of about 46 km from the source of the Godavari River. Waste water from 78 MLD Sewage treatment plant enters in to the Godavari River after treatment at this point.

9 **Sampling Station (SS_8): Dasak Village:** This sampling station is located at Dasak Village with a distance of 6 km from the SS_7 and at a total distance of about 52 km from the source of the Godavari River. Ashes of human bodies from the crematoria's are mixed with the water of the Godavari River before the station. Besides this the sewage water is also released from the washing activities of animals, cloth, vehicles, hotel, restaurant, pathological laboratories, nursing homes etc in this area and ultimately reached to the Godavari River. Oil and grease from washing of vehicles, Solid waste from the houses and surrounding shops, Domestic waste water, Construction debris, Waste water overflowing from septic tanks, Hospital waste etc. are mixed some times of very

little quantity with the Godavari River water.

10 **Sampling station (SS_9): Saikheda Village** This sampling station is located at Saikheda village which is at the distance of 23 km from the SS_8 with total distance of about 75 km from the source of the Godavari River. Ashes of human bodies from the crematoria's are mixed with the water of the Godavari River before the station. Besides this the sewage water is also released from the washing activities of animals, cloth, vehicles, hotel, restaurant, pathological laboratories, nursing homes etc in this area and ultimately reached to the Godavari River. Oil and grease from washing of vehicles, Construction debris, Waste water overflowing from septic tanks, Hospital waste etc. are mixed some times of very little quantity with the Godavari River water.

The brief summaries of sampling station and effluents or domestic sewage are confluenced with the Godavari River water before the respective sampling stations are tabulated in Table 4.2

Table 4.2 Sampling Location Details With Present Activities:

Sl. No.	Sampling station (SS)	Location	Distance from previous SS (km)	Distance from sources of Godavari River (km)	Confluence of effluent/ sewage before SS from
1.	SS_0	Kushawart	0	10	Bathing,
2.	SS_1	Gangapur Dam	18	28	Storage only
3.	SS_2	Someshwar	06	34	Bathing,Cloth,Vehicle Washing
4.	SS_3	Anandwali	05	39	Cloths, animals Washing
5.	SS_4	Victoria Bridge	03	42	Bathing,Cloth,Vehicle Washing
6.	SS_5	Ramkund	01	43	Bathing,cloth,Vehicle

					Washing
7.	SS_6	Goda Kapila sangam	02	45	Kapila River mixing, Cloth Washing
8.	SS_7	D/S of Nashik	01	46	Treated waste water mixing
9.	SS_8	Dasak Village	06	52	Bathing,Cloth,Vehicle Washing
10.	SS_9	Saikheda Village	23	75	Cloths, animal, Vehicle Washing

The locations of sampling stations are shown at the Godavari River Maps and also shown the photographs of the said sampling stations.

4.3 WATER QUALITY SAMPLING

The first step of the sampling programme was to conduct a preliminary survey along the River Godavari and its tributaries and incoming drains so as to be able to select sampling locations which will be representative of the entire river and also to identify the river water uses and polluting activities. The next step was the selection of the physico- chemical and bacteriological parameters for monitoring of the river water.

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.

Water Sampling Methods

The grab samples were collected for all sampling locations.

Water samples for chemical analysis: The water samples were collected from a depth of 20-30 cm from the river by the plastic containers of 2 liter of capacity, provided with double cap device. The samples were collected up to the top, without leaving any space so as to prevent the premature release of dissolved gases during the transit period.

Water samples of bacteriological analysis: The water samples were collected from 30 cm depth of the river in properly sterilized neutral glass bottles of 120 ml capacity. Some space was left for air for survival of bacteria. The water sample were analysed within 24 hours from collection.

4.4 SAMPLING PROGRAMME

Water samples were collected and analysed in the two months 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. The following sampling schedule is mentioned in Table 5.2.Sampling was done in the month of December 2007 and February 2008. Considering the amount of efforts required, time and resources available, sampling was done for two months as the secondary data were available for more than 5 years.

4.5. EXPERIMENTAL METHODS

The water quality for a given use depends on the following:

a. Parameters which significantly affect the utility for the use
b. Individual values of each significant parameter
c. The relative importance of various relevant parameters for that particular use

Considering above points, following water quality parameters were determined; temperature, pH, DO, BOD, COD, total solids, total suspended solids, total dissolved solids, turbidity, specific conductivity, nitrate, phosphate, total coliform (MPN), faecal coliform and heavy metals. Physico-chemical and bacteriological parameters were evaluated according to methods specified in "Standard Methods for the Examination of water and Wastewater" (APHA-AWWA-WPCF 1995).

4.6 DATA COLLECTION AND WATER SAMPLING

The data collected for the study of river water pollution is basically the physiochemical analysis of river water samples. Depending on the major sources of waste water / pollutants 10 sampling stations were selected along the flow from Kushawart Trimbakeswar to Saikheda Village. The samples were analysed in the pollution control laboratory and Om laboratory for different parameters of physical chemical and biological aspects. Samples were collected at all ten locations in the month December 2007 and February 2008. Results of the analysis are tabulated in tables. The Samples were collected in two litre plastic cans, labeled with name of sampling spot & date of collection. Samples were immediately sent for analysis except dissolved oxygen. Samples for DO were taken in DO bottle of 300 ml capacity. DO was fixed on the site immediately after filling the DO bottles by adding 2 ml of MnSo4 solution followed by 2ml alkali iodide azide solution to each bottle was stopper properly maintaining water seal upto laboratory.

Samples were analysed for parameters like SS, TDS, BOD, COD, pH, Total Hardness, Calcium Hardness, Total alkalinity, chlorides, sodium, potassium, Sulphate, phosphate, nitrate, Faecal coliform, electrical conductivity, each parameter is having its unique importance & is linked to specific source of pollution so all of them are considered of equal importance .

Table 4.3 Primary Water Quality Data collection schedule for study stretch

Sr. No.	Sampling Points/ Locations	Distance from origin in kms	Data collected on		Remarks/ Activities
1	Kushawart	10	20.12.2007	22.02.2008	Bathing,
2	Gangapur Dam	28	22.12.2007	24.02.2008	Storage only
3	Someshwar	34	22.12.2007	24.02.2008	Bathing,Cloth,Vehicle Washing
4	Anandwali	39	22.12.2007	24.02.2008	Cloths, animals Washing
5	Victoria Bridge	42	23.12.2007	25.02.2008	Bathing,Cloth,Vehicle Washing
6	Ramkund	43	23.12.2007	25.02.2008	Bathing,cloth,Vehicle Washing
7	Goda Kapila sangam	45	24.12.2007	26.02.2008	Kapila River mixing, Cloth Washing
8	D/S of Nashik	46	24.12.2007	26.02.2008	Treated waste water mixing
9	Dasak Village	52	25.12.2007	27.02.2008	Bathing,Cloth,Vehicle Washing
10	Saikheda Village	75	25.12.2007	27.02.2008	Cloths, animal, Vehicle Washing

Table 4.4 Analysis Results with NSFWQI for Primary Data

December 2007

Parameters	S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
P^H	7.11	8.10	7.78	7.86	8.27	7.50	7.60	7.75	7.6	7.86
DO	1.95	6.8	7.0	5.7	4.7	5.0	4.0	4.6	4.8	3.60
BOD	85	5.1	5.7	8.0	8.1	10.3	11.8	15	21	9
COD	152	21	24	29	30	40	37	40	36	44
Total Hardness	100	78	118	114	135	190	196	198	230	236
Calcium Hardness	120	46	78	70.6	81	122	1	40	46	49
Magnesium Hardness	11.67	32	40	43.4	54	68	89	17.02	27	25.3
Electrical Conductivity	379	200	279	154	170	160	160	594	523	270
Chlorides	37	11	18	69	89	100	1	50	41	35
Sodium	18	6.0	11	10	17	21	27	28	25	29
Sulphates	29	5.16	17	29	24	14.6	14.5	38.2	59	0.48
Phosphates	.450	0.011	0.06	0.05	0.07	0.04	0.07	2.94	0.54	0.50
Nitrate	0.478	0.23	0.27	1.39	1.81	0.8	1.12	0.021	2.89	0.03
TSS	16	22	25	35	34	49	46	49	30	52
TDS	210	180	490	335	535	299	155	487	212	215

February 2008

Parameters	S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
P^H	7.01	7.30	7.99	7.91	8.30	7.20	7.10	7.69	7.68	7.78
DO	1.9	7.5	7.4	5.8	4.7	4.8	3.1	1.6	4.17	3.40
BOD	24	4.8	5.9	7.3	7.60	9.8	10.3	36	24	12
COD	40	28	19	21	33	24	33	84	40	32
Total Hardness	140	126	126	127	191	96	214	-	260	256
Calcium Hardness	64	92	80	81.2	122	66	148	-	56	99
Magnesium Hardness	2.44	34	46	45.8	69	30	66	-	3.76	29.3
Electrical Conductivity	426.5	189	248	296	378	370	620	599.5	-	240
Chlorides	53	17	19	37	62	93	129	85	37.5	45
Sodium	19	25	5.0	8.5	9.5	16.5	35	-	-	39
Sulphates	18	3.28	27	23	25	15.4	16.6	-	75	68
Phosphates	0.358	0.015	0.5	0.14	0.21	0.	0.04	-	0.52	0.90
Nitrate	0.833	0.15	0.90	1.93	2.23	0.97	0.99	-	3.76	0.13
Total Suspended Solids	27	45	51	36	26	41	51	40	35	52
Total Dissolved Solids	340	165	149	139	221	156	597	212	166	215

Table 4.5 **Analysis Results with NSFWQI for Secondary Data**

Year-2002 **Gangapur Dam Nasik**

MONTHS	PH	BOD	COD	DO	TOTAL COLIFORM	Temp.	Index
Jan	8.5	4.8	202	6.8	170	28	36
Feb	8	6	20.6	5.4	175	29	
Mar	8.3	4.4	20.4	6.2	200	28	
Apr	7	6	20	6.4	225	29	
May	7.5	5	20	7	175	30	
Jun	7.7	5.5	16	6.2	350	24	
July	7.6	9	32	6.2	225	23	
Aug	7.6	5	16	6	175	22	
Sept	8.1	5.5	16	6.5	175	20	
Oct	8.5	9	24	5.9	225	23	
Nov	7.4	4	16	6.7	275	24	
Dec	8.2	7	24	6.8	250	22	
Average	**7.86**	**5.9**	**35.583**	**6.34**	**218.3**	**24.4**	

Year-2002 **Godavari River Ramkund Nasik**

MONTHS	PH	BOD	COD	DO	TOTAL COLIFORM	Temp.	Index
Jan	7.4	10.8	24	3.2	250	20	35
Feb	7.3	7	26	4	350	29	
Mar	8	4	16	6.8	250	30	
Apr	7.4	7	24	6.7	150	25	
May	7.3	5	20	6	175	21	
Jun	7.2	35	56	3.5	225	24	
July	7.7	5.5	24	5.5	175	29	
Aug	7.6	4	16	6.9	175	26	
Sept	8	5	16	7.5	120	27	
Oct	7.4	10	32	3.8	200	24	
Nov	7.5	3	20	6.3	140	29	
Dec	7.8	8	28	6.5	200	28	
Average	**7.55**	**8.69**	**25.167**	**5.558**	**200.83**	**27**	

Year-2002 **Godavari River D/S of Nasik**

MONTHS	PH	BOD	COD	DO	TOTAL COLIFORM	Temp.	Index
Jan	7.2	7.4	28	3.6	350	23	34
Feb	7.5	10	29	4.4	170	21	
Mar	7.9	3	30	7	250	25	
Apr	7.0	5	20	5.7	350	30	
May	7.3	8	44	5.9	115	27	
Jun	7.2	36	52	3.5	175	29	
July	7.8	10	40	5.3	170	25	
Aug	7.7	4	20	6.5	150	24	
Sept	8.0	2	24	7	275	24	
Oct	7.6	8.5	24	4.8	175	29	
Nov	7.5	4	24	7	110	28	
Dec	7.8	5	20	7	350	25	
Average	**7.54**	**8.57**	**29.583**	**5.64**	**220**	**25.83**	

Year-2003 **Gangapur Dam Nasik**

MONTHS	PH	BOD	COD	DO	TOTAL COLIFORM	Temp.	Index
Jan	8.3	4.4	20.4	6.2	200	22	38
Feb	8	6	20.6	5.4	175	27	
March	8.5	4.8	24	6.8	170	25	
Apr	7.8	3.2	18.6	7.78	525	32	
May	7.6	4.6	20.4	6.9	204	27	
Jun	8.6	5.7	25.8	6.2	202	29	
July	8.1	7.1	21.2	6.6	14.7	25	
Aug	7.9	5.6	29.2	7.1	192	23	
Sept	7.8	21	60.2	5.8	139	32	
Oct	8.1	5.6	26.1	7.2	21.6	32	
Nov	8.4	9.4	36.4	6.8	850	24	
Dec	7.4	6.2	28.3	7.6	4.8	30	
Average	**8.041**	**6.97**	**27.6**	**6.69**	**224.84**	**27.33**	

Year-2003 Godavari River Ramkund Nasik

MONTHS	PH	BOD	COD	DO	TOTAL COLIFORM	Temp.	Index
Jan	8	4	16	6.8	250	28	34
Feb	7.4	10.8	24	3.2	250	29	
Mar	7.3	7	26	4	350	28	
Apr	8.2	3.9	52.6	6.7	421	29	
May	6.6	6.2	32.5	4.6	225	30	
Jun	8.1	7.6	27.8	5.9	205	24	
July	7.4	2.9	32.6	7.8	213	23	
Aug	7.4	4.2	31.6	7.2	421	22	
Sept	7.6	6.4	52.8	7.6	221	20	
Oct	7.9	2.8	35	7.2	232	23	
Nov	7.1	41.6	49.2	5.6	750	24	
Dec	7.6	2.9	40	7.6	232	22	
Average	**7.55**	**8.35**	**35**	**6.18**	**314.77**	**24.4**	

Year-2003 **Godavari River D/S of Nasik**

MONTHS	PH	BOD	COD	DO	TOTAL COLIFORM	Temp.	Index
Jan	7.9	3	30	7	250	20	
Feb	7.5	10	29	4.4	170	24	
Mar	7.2	7.4	28	3.6	350	28	
Apr	7.6	7.2	26	5.2	525	34	
May	7.0	14.6	39.8	7.2	308	22	
Jun	7.6	12.5	36	7.6	314	24	
July	7.6	18.5	39.6	5.2	306	27	
Aug	7.6	26.5	52.5	4.7	292	29	
Sept	7.4	18.9	39.2	5.6	242	26	35
Oct	7.6	12.5	24.6	6.8	325	34	
Nov	7.4	16.2	36.5	5.2	292	27	
Dec	7.6	12.8	29.6	8.5	242	36	
Average	**7.5**	**13.34**	**34.22**	**5.91**	**301.33**	**27.83**	

Year-2004 **Gangapur Dam Nasik**

MONTHS	PH	BOD	COD	DO	TOTAL COLIFORM	Temp.	Index
Jan	8.3	4.4	20.4	6.2	200	28	40
Feb	8	6	20.6	5.4	175	29	
Mar	8.5	4.8	20.2	6.8	170	28	
Apr	7.8	3	18.4	7.4	550	29	
May	7.2	4	20.2	6.3	200	30	
Jun	8.2	5	25.8	6.6	225	24	
July	8.2	7	22.2	6.5	14	23	
Aug	8.1	5.5	30.2	7.2	196	22	
Sept	7.9	22	60.2	5.9	140	20	
Oct	8.2	5	27.5	7.6	22	23	
Nov	8.9	9	36.8	6.8	900	24	
Dec	7.8	6	28.1	7.2	4	22	
Average	**8.09**	**6.8**	**27.85**	**6.66**	**233**	**24.4**	

Year-2004 Godavari River Ramkund Nasik

MONTHS	PH	BOD	COD	DO	TOTAL COLIFORM	Temp.	Index
Jan	7.2	3	16	7	280	32	
Feb	7.7	4	24	7.1	250	31	
Mar	7.8	7	26	5.8	350	32	
Apr	8	3	54	6.6	425	29	
May	6.7	6	38	4.9	250	32	
Jun	8.2	7.5	28	5.8	250	26	
July	7.8	2	39	7.9	14	25	
Aug	7.5	3	32	7.1	425	22	
Sept	7.9	6	54	7.4	220	30	40
Oct	7.6	2	35	7.3	220	24	
Nov	7.2	48	43	5.7	900	30	
Dec	7.5	2	41	7.2	220	28	
Average	7.59	7.79	35.83	6.65	317	28.41667	

Year-2004 Godavari River D/S of Nasik

MONTHS	PH	BOD	COD	DO	TOTAL COLIFORM	Temp.	Index
Jan	6.9	14	42	6.9	300	23	40
Feb	7.2	10	29	6.9	350	21	
Mar	7.7	20	58	4.1	400	25	
Apr	7.8	4	13	5.1	550	30	
May	6.9	14	39	6.9	306	27	
Jun	7.2	10	32	6.9	312	29	
July	7.7	15	41	5.1	309	25	
Aug	7.1	20	54	4.1	290	24	
Sept	7.3	13	38	5.9	245	24	
Oct	7.4	10	28	6.2	350	29	
Nov	7.3	14	39	5.8	298	28	
Dec	7.2	12	32	7	240	25	
Average	**7.30**	**13**	**37**	**5.9**	**329**	**25.88**	

Year-2005 Gangapur Dam Nasik

MONTHS	PH	BOD	COD	DO	TOTAL COLIFORM	Temp.	Index
Jan	8.3	4.4	20.4	6.2	200	28	
Feb	8	6	20.6	5.4	175	29	
Mar	8.5	4.8	202	6.8	170	28	
Apr	8.5	5.5	51	7.1	23	29	
May	7.6	6.9	58	7.2	9.4	30	42
Jun	7.3	9.4	21.5	5.6	197	24	
July	7.6	5.6	19.4	7.1	1806	23	
Aug	7.6	15.4	42	5.8	45	22	
Sept	7.6	5.6	19	6.5	276	20	
Oct	8.6	8.9	28.9	7.2	17.5	23	
Nov	7.5	5.6	22.5	7.6	6.9	24	
Dec	8.2	5.8	22.5	7.1	18.5	22	
Average	**7.94**	**6.99**	**43.98**	**6.63**	**245.66**	**24.4**	

Year-2005 Godavari River Ramkund Nasik

MONTHS	PH	BOD	COD	DO	TOTAL COLIFORM	Temp.	Index
Jan	8	4	16	6.8	250	23	40
Feb	7.4	10.8	24	3.2	250	21	
Mar	7.3	7	26	4	350	25	
Apr	7.4	6	22	7.2	1100	30	
May	7.9	5	70	6.5	130	27	
Jun	7.3	9	26	5.2	225	29	
July	7.9	10	3.2	6.2	900	25	
Aug	7.6	13	39	5.7	355	24	
Sept	7.8	5.9	23	6.7	13	24	
Oct	8.2	8.6	26	6.8	142	29	
Nov	8.2	4.6	18	7.4	26.5	28	
Dec	7.8	9.2	23.5	1.8	115	25	
Average	**7.73**	**7.758**	**26.39**	**5.62**	**321.35**	**25.67**	

Year-2005 **Godavari River D/S of Nasik**

MONTHS	PH	BOD	COD	DO	TOTAL COLIFORM	Temp.	Index
Jan	6.9	3	30	7	250	32	41
Feb	7.2	10	29	4.4	170	24	
Mar	7.7	7.4	28	3.6	350	29	
Apr	7.5	8.0	32	6.5	900	30	
May	7.8	10	29	5.9	175	32	
Jun	7.6	14	38	5.2	225	28	
July	7.7	30	36	4.5	1600	23	
Aug	7.4	14	32	4.9	425	26	
Sept	7.9	11	32	7	20	20	
Oct	7.8	13	36	5.5	1580	23	
Nov	8.21	9	29	6.4	1579	24	
Dec	7.8	7	22	6.2	5500	22	
Average	**7.62**	**11.36**	**31.08**	**5.59**	**1064.5**	**26.83**	

Table 4.6 Secondary Data: Analysis Results of Godavari River for the Year 2003

pH

Month	Gangapur Dam	Someshwar	Anandwali	Victoria Bridge	Ramkund	Down stream
Jan.03	7.70	8.10	8.21	8.15	7.60	7.50
Feb.03	7.80	8.30	8.16	8.00	7.70	7.60
Mar.03	8.40	8.40	8.08	8.35	7.50	7.60
Apr.03	7.30	7.99	7.91	8.30	7.20	7.10
Sept.03	8.10	7.78	7.86	8.27	7.50	7.60
Oct.03	8.30	7.78	7.90	8.29	7.20	7.10
Nov.03	8.20	7.78	7.73	7.90	7.60	7.50
Dec.03	7.90	7.85	7.70	7.46	7.10	7.20

Dissolved Oxygen

Month	Gangapur Dam	Someshwar	Anandwali	Victoria Bridge	Ramkund	Down stream
Jan.03	5.8	5.9	4.8	4.6	4.8	3.5
Feb.03	6.50	6.6	4.9	4.9	5.1	3.9
Mar.03	7.4	7.6	5.7	5.0	5.1	4.9
Apr.03	7.5	7.4	5.8	4.7	4.8	3.1
Sept.03	6.8	7.0	5.7	4.7	5.0	4.0
Oct.03	6.8	6.9	4.9	4.4	4.7	4.6
Nov.03	6.1	7.0	5.1	4.6	4.9	4.5
Dec.03	5.9	6.5	5.0	4.0	4.4	4.2

Biological Oxygen Demand

Month	Gangapur Dam	Someshwar	Anandwali	Victoria Bridge	Ramkund	Down stream
Jan.03	4.0	7.5	8.5	8.5	8.10	18.9
Feb.03	6.0	6.9	8.3	8.0	9.0	13.0
Mar.03	4.5	5.5	6.0	7.0	11.0	11.90
Apr.03	4.8	5.9	7.3	7.60	9.8	10.3
Sept.03	5.1	5.7	8.0	8.1	10.3	11.8
Oct.03	4.4	6.8	9.0	15	23.6	26.0
Nov.03	4.8	8.5	9.0	12.5	16.9	18.0
Dec.03	5.0	9.9	21.0	23.8	26.0	30.0

Total Suspended Solids

Month	Gangapur Dam	Someshwar	Anandwali	Victoria Bridge	Ramkund	Down stream
Jan.03	32	35	30	36	51	46
Feb.03	53	61	31	34	57	49
Mar.03	21	27	26	32	52	59
Apr.03	45	51	36	26	41	51
Sept.03	22	25	35	34	49	46
Oct.03	28	31	34	31	50	62
Nov.03	24	26	26	69	47	57
Dec.03	41	49	35	26	46	65

Total Dissolved Solids

Month	Gangapur Dam	Someshwar	Anandwali	Victoria Bridge	Ramk und	Down stream
Jan.03	123	781	530	639	342	341
Feb.03	121	530	654	211	338	401
Mar.03	159	221	390	217	361	378
Apr.03	165	149	139	221	156	597
Sept.03	180	490	335	535	299	155
Oct.03	128	471	520	331	230	466
Nov.03	116	781	421	731	142	156
Dec.03	166	790	630	846	224	599

4.7 COMPUTATION OF NSF WATER QUALITY INDICES

The NSFWQI was calculated using a software which was available on the internet from the site of the Wilkes University, Centre for Environmental Quality,PennsylvaniaU.S.A.,viz.www.waterresearch.net/watrqualindex/waterqualityind ex htm ,to calculate the index, firstly, dissolved oxygen concentration had to be converted into percent saturation. Secondly, entered the concentration values of the pollutant variables one by one in the spaces provided in the software and note the sub index value that was returned. These sub index values were then inputted in a different table, which aggregated them and returned the NSFWQI value of the particular location and then by repeating the same procedure the NSFWQI is obtained for all the sampling locations shown in table 5.2 and table 5.3 for primary and secondary data.

Some sample calculations of NSFWQI for primary data, secondary data , and NSFWQI results for all the primary and secondary data are shown in results sheets at table 5.1 -5.4 in the next chapter on page nos.114-119 respectively.

Table 4.7 Secondary data of Godavari River water quality for the year 2006-2007

Month & Year: Jan-06

Parameters	Temp	PH	DO	BOD	COD	Total Coli form	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	22	7.2	7.1	5.5	7.5	9	21	159	1.5	118	27	8.5	50	38	4.82	0.04	0.77
Someshwar	23	8.4	7.6	5.5	30	120	27	221	1.05	189	21	6.75	82	38	12.2	0.8	0.41
Anandwali	21	8.08	5.7	6	25	160	26	390	2	271	31	12.25	105.2	54.4	42	0.8	0.89
Victoria Bridge	24	8.35	5	7	29	280	32	217	3.5	366	71	20	170	110	32.5	0.63	1.65
Ramkund	20	7.5	5.2	15	27	251	52	361	4.85	500	77	29	141	75	15.6	0.09	1.01
D/S of Nasik	23	7	3.8	22	57	26	59	378	6.5	550	112	36	147	73	19.6	0.224	0.96

Month & Year:Feb-06

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	32	8.2	5.7	21.5	14	14	21	159	1.5	159	27	8.5	59	38	4.82	0.04	0.77
Someshwar	28	7.9	5.6	5.5	39	120	27	221	1.05	198	21	6.75	86	38	12.2	0.8	0.41
Anandwali	32	7.6	4.7	6	29	163	26	390	2	276	31	12.25	107	54.4	42	0.8	0.89
Victoria Bridge	35	8.3	4	7	39	289	32	217	3.5	369	71	20	176	110	32.5	0.63	1.65
Ramkund	29	7.4	8.2	17.5	42	62	52	361	4.85	525	77	29	148	75	15.6	0.09	1.01
D/S of Nasik	21	7.2	2.6	32	64	49	59	378	6.5	515	112	36	146	73	19.6	0.224	0.96

Month & Year:Mar-06

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	29.2	8.2	6.2	18	22	6.5	32	205	32	158	30	12	13.6	3.4	12	0.34	0.473
Someshwar	29	8.35	6.2	6.75	28	7	45	307	30	369	24	13	18	2	4	0.19	0.451
Anandwali	34	7.94	5.7	6.25	16	17	46	238	46	189	23	40	20	4.38	28.6	1.93	0.484
Victoria Bridge	35	7.2	4.6	28	24	18	52	367	49	234	29	41	23	7	38	1.98	0.49
Ramkund	31	7.6	6.8	14.8	41	32	45	165	0.41	264	17	25	92	34	3.28	0.015	0.15
D/S of Nasik	25	7.6	6.4	4.8	18	42	51	149	0.82	248	19	5	80	46	27	0.5	0.9

All Parameters are in mg/lit except PH, Temperature (°C), and Turbidity (NTU), Conductivity (µs/cm).

Month & Year:Apr-06

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	31	7.3	7.1	5	12	9	45	165	41	162	17	25	92	34	3.28	0.015	0.15
Someshwar	25	7.99	7.4	5.9	19	126	51	149	82	248	19	48	80	46	27	0.5	0.9
Anandwali	27	8.16	6.2	17	56	67	32	198	45	122	45	41	78	67	34	0.0067	0.87
Victoria Bridge	31	7.3	7.5	4.8	28	126	45	165	49	186	17	25	92	34	3.28	0.015	0.15
Ramkund	25	6.7	5.5	14	29	609	51	149	78	192	29	5	80	46	27	0.5	0.9
D/S of Nasik	31	7.6	7.2	12	32	116	34	167	89	389	52	56	78	54	24	0.77	0.95

Month & Year:May-06

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	31	8.1	5.7	22	14	14.6	45	165	34	196	12	25	92	34	3.28	0.015	0.15
Someshwar	25	7.99	6.2	5.9	19	129	51	149	54	256	19	5	80	46	27	0.5	0.9
Anandwali	31	7.3	5.9	4.8	28	145	45	165	67	192	28	25	92	34	3.28	0.015	0.15
Victoria Bridge	25	7.99	6.1	5.9	19	126	51	149	49	254	19	5	80	46	27	0.5	0.9
Ramkund	36	8.1	3.5	24	58	110	48	156	52	183	43	3	89	54	35	0.56	0.96
D/S of Nasik	37	8.2	3.7	20	56	25	37	158	43	196	39	5	94	61	43	0.64	0.87

Month & Year:Jun-06

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	29.2	8.6	6.2	22	22	6	32	205	32	147	30	12	13.6	3.4	12	0.34	0.473
Someshwar	29	8.35	6.2	6.75	28	7	45	307	30	358	24	13	18	2	4	0.19	0.451
Anandwali	37	7.6	5.1	33	76	187	37	158	43	191	39	5	94	61	43	0.64	0.87
Victoria Bridge	31	7.3	7.5	4.8	28	126	45	165	67	178	17	25	92	34	3.28	0.015	0.15
Ramkund	25	7.4	3.5	32	71	250	51	149	89	134	19	5	80	46	27	0.5	0.9
D/S of Nasik	32	7.1	2.5	32	64	50	45	187	65	204	29	34	87	38	87	0.87	0.89

All Parameters are in mg/lit except PH, Temperature (°C), and Turbidity (NTU), Conductivity (µs/cm).

Month & Year:Jul-06

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	29.2	7.8	7.3	5	12.5	25	32	205	32	164	30	12	13.6	3.4	12	0.34	0.473
Someshwar	29	8.35	6.2	9	28	7	45	307	30	373	24	13	18	2	4	0.19	0.451
Anandwali	31	7.3	7.5	48	28	126	45	165	0.41	196	17	25	92	34	3.28	0.015	0.15
Victoria Bridge	25	7.99	7.4	59	19	126	51	149	0.82	234	19	5	80	46	27	0.5	0.9
Ramkund	31	7.64	8.6	4	12.5	25	45	165	0.41	172	17	25	92	34	3.28	0.015	0.15
D/S of Nasik	25	7.99	6.4	4	18	45	51	149	0.82	231	19	5	80	46	27	0.5	0.9

Month & Year:Aug-06

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	37	7.2	7.9	5.5	15	17	37	158	43	189	39	5	94	61	30	0.64	0.87
Someshwar	31	7.2	6.4	5.6	28	189	45	165	42	196	17	25	92	45	28	0.015	0.15
Anandwali	25	7.99	6	5.9	19	165	51	149	56	250	23	5	80	46	27	0.5	0.9
Victoria Bridge	31	7.3	5.4	4.8	28	126	45	165	59	181	24	25	92	34	73	0.015	0.15
Ramkund	25	7.5	8.1	8	15.2	65	51	149	65	242	45	5	80	51	45	0.5	0.9
D/S of Nasik	24	7.4	7.6	10	32	115	56	245	87	249	58	6	67	56	67	0.98	0.89

Month & Year:Sep-06

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	29.2	7.9	7.1	6.5	17	25	32	205	32	143	30	12	13.6	3.4	12	0.34	0.473
Someshwar	29	8.35	6.2	6.75	28	71	45	307	30	376	24	13	18	2	4	0.19	0.451
Anandwali	37	7.6	5.1	33	76	187	37	158	43	189	39	5	94	61	43	0.64	0.87
Victoria Bridge	31	7.3	6.3	4.8	28	126	45	165	41	178	17	25	92	34	3.28	0.015	0.15
Ramkund	25	7.8	6.7	13	12.5	35	51	149	56	146	19	5	80	46	27	0.5	0.9
D/S of Nasik	24	7.4	6.3	10.5	31	45	43	204	62	195	41	32	82	52	32	0.63	0.91

ll Parameters are in mg/lit except PH, Temperature (°C), and Turbidity (NTU), Conductivity (µs/cm).

Month & Year:Oct-06

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	29.2	7.9	4.6	5	12.5	25	32	205	32	162	30	12	13.6	3.4	12	0.34	0.473
Someshwar	29	8.35	6.2	6.75	21	7	45	307	30	376	24	13	18	2	4	0.19	0.451
Anandwali	32	7.7	5	34	34	112	38	306	48	169	45	21	45	45	34	0.34	0.48
Victoria Bridge	31	7.3	6.2	4.8	28	126	45	165	49	164	48	25	92	34	56	0.015	0.15
Ramkund	25	7.2	5.4	10	21.5	55	51	149	56	249	65	29	80	46	27	0.5	0.9
D/S of Nasik	37	7.5	4.8	9	24	85	37	158	64	181	79	5	94	61	43	0.64	0.87

Month & Year:Nov-06

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	29.2	7.9	7.2	8.5	18.5	16	32	205	32	134	30	12	13.6	3.4	12	0.34	0.473
Someshwar	29	7.5	6.2	6.75	28	7	45	307	30	378	24	13	18	2	4	0.19	0.451
Anandwali	31	7.3	7.5	32	28	126	45	165	48	179	17	25	92	34	3.28	0.015	0.15
Victoria Bridge	25	7.99	7.4	5.9	19	126	51	149	76	262	19	5	80	46	27	0.5	0.9
Ramkund	37	7.4	5.7	7.8	18.5	17	37	158	43	165	39	5	94	61	43	0.64	0.87
D/S of Nasik	35	7.7	5.78	9	22	18	28	324	52	179	48	19	93	72	43	0.72	0.24

Month & Year:Dec-06

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	31	7	6.9	8	21	25	32	205	32	169	30	12	13.6	3.4	12	0.34	0.473
Someshwar	29	8	6.2	6.75	28	12	45	307	30	362	24	13	18	2	4	0.19	0.451
Anandwali	34	6.9	7.5	21	32	178	45	165	39	204	17	25	92	34	3.28	0.015	0.15
Victoria Bridge	25	7.9	7.4	5.9	19	126	51	149	45	232	19	5	80	46	27	0.5	0.9
Ramkund	31	7.1	6.8	8.6	21.5	1800	45	165	43	204	17	25	92	34	3.28	0.015	0.15

D/S of Nasik	25	7.2	6.5	5.2	11.4	1200	51	149	49	209	19	5	80	46	27	0.5	0.9

All Parameters are in mg/lit except PH, Temperature (^oC), and Turbidity (NTU), Conductivity (µs/cm).

Month & Year:Jan-07

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	18	7.9	7	5	12.5	25	3	267	32	195	16.5	34	21	4	32	1.18	2.52
Someshwar	35	7.2	4.6	28	24	18	52	367	49	234	29	41	23	7	38	1.98	0.49
Anandwali	34	7.94	5.7	6.25	16	17	46	238	46	189	23	40	20	4.38	28.6	1.93	0.484
Victoria Bridge	35	7.2	4.6	28	24	18	52	367	49	236	29	41	23	7	38	1.98	0.49
Ramkund	34	5.9	6.3	7	21	1800	46	238	46	196	23	40	20	4.38	28.6	1.93	0.484
D/S of Nasik	35	6.5	5.4	9.5	22	900	52	367	49	239	29	41	23	7	38	1.98	0.49

Month & Year:Feb-07

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	34	7.5	6	5.8	13.5	25	46	238	46	196	23	40	20	4.38	28.6	1.93	0.484
Someshwar	35	7.2	4.6	28	24	18	52	367	49	232	29	41	23	7	38	1.98	0.49
Anandwali	18	7.92	7.38	3	32	17	3	267	32	198	16.5	34	21	4	32	1.18	2.52
Victoria Bridge	35	7.2	4.6	28	24	18	52	367	49	229	29	41	23	7	38	1.98	0.49
Ramkund	31	7.5	6.4	6.2	18	1600	45	165	0.41	171	17	25	92	34	3.28	0.015	0.15
D/S of Nasik	25	7.5	5.9	9.6	27	1800	51	149	0.82	141	19	5	80	46	27	0.5	0.9

Month & Year:Mar-07

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	31	7.4	6.58	5	14.5	35	45	165	0.41	176	17	25	92	34	3.28	0.015	0.15
Someshwar	25	7.99	7.4	5.9	19	126	51	149	0.82	241	19	5	80	46	27	0.5	0.9
Anandwali	30	7.91	5.8	7.3	21	127	36	139	1.3	299	37	8.5	81.2	45.8	23	0.14	1.93
Victoria Bridge	31	8.3	4.7	7.6	33	191	26	221	1.4	376	62	9.5	122	69	25	0.21	2.23

Ramkund	24	7.2	5.9	6.3	15	900	41	156	1.3	364	93	16.5	66	30	15.4	0	0.97
D/S of Nasik	21	7.3	5.4	7.9	21	1600	51	597	6.4	619	129	35	148	66	16.6	0.04	0.99

All Parameters are in mg/lit except PH, Temperature (^{o}C), and Turbidity (NTU), Conductivity (μs/cm).

Month & Year:Apr-07

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	29.2	7	5.7	5	20	350	32	205	32	192	30	12	13.6	3.4	12	0.34	0.473
Someshwar	29	8.35	6.2	6.75	28	7	45	307	30	376	24	13	18	2	4	0.19	0.451
Anandwali	32	8.03	5.1	12	56	12	56	403	36	402	34	21	19	5	34	1.67	0.432
Victoria Bridge	36	7.99	5	23	28	34	59	389	51	392	37	32	26	9	29	1.87	0.411
Ramkund	34	8.2	6.2	18	22	6.5	46	238	46	206	23	40	20	4.38	28.6	1.93	0.484
D/S of Nasik	29	8.1	5.7	22	14	14.6	42	321	56	382	56	30	40	14	45.2	2.05	0.386

Month & Year:May-07

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	29.2	7.3	5.9	8	44	115	32	205	32	145	30	12	13.6	3.4	12	0.34	0.473
Someshwar	29	8.35	6.2	6.75	28	7	45	307	30	372	24	13	18	2	4	0.19	0.451
Anandwali	32	7.9	4.9	21	32	12	48	306	36	435	32	19	17	4	34	0.31	0.46
Victoria Bridge	36	7.99	5	23	28	34	59	389	51	396	37	32	26	9	29	1.87	0.411
Ramkund	34	7.3	7.1	5	12	9	46	238	46	128	23	40	20	4.38	28.6	1.93	0.484
D/S of Nasik	35	8.6	6.2	20	22	6	52	367		131	29	41	23	7	38	1.98	0.49

Month & Year:Jun-07

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	29.2	7.2	3.5	36	52	175	32	205	32	169	30	12	13.6	3.4	12	0.34	0.473
Someshwar	29	8.35	6.2	6.75	28	7	45	307	30	361	24	13	18	2	4	0.19	0.451

Anandwali	34	7.94	5.7	6.25	16	17	46	238	46	199	23	40	20	4.38	28.6	1.93	0.484
Victoria Bridge	35	7.2	4.6	28	24	18	52	367	49	232	29	41	23	7	38	1.98	0.49
Ramkund	31	8.1	5.7	22	14	14.8	31	440	56	172	32	49	16	4.3	48	0.39	0.54
D/S of Nasik	22	7.8	7.3	5	12.5	25	67	463	51	189	37	54	19	3.2	54.78	0.23	0.78

All Parameters are in mg/lit except PH, Temperature (°C), and Turbidity (NTU), Conductivity (µs/cm).

Month & Year:Jul-07

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	29.2	7.8	5.3	10	40	170	32	205	32	132	30	12	13.6	3.4	12	0.34	0.473
Someshwar	29	8.35	6.2	6.75	28	7	45	307	30	358	24	13	18	2	4	0.19	0.451
Anandwali	25	8.18	5.8	7	28	20	28	268	15	246	30	17	23	3	45	1.38	2.64
Victoria Bridge	27	8.29	6.2	7.5	12	25	32	307	42	243	31	17.5	45.6	21.4	44	0.55	2.82
Ramkund	31	7.9	4.6	5	12.5	35	56	540	52	276	45	19	46	12	49	0.67	1.82
D/S of Nasik	28	7.2	7.9	5.5	15	17	34	274	45	251	40	20	56	21.49	48	0.63	1.97

Month & Year:Aug-07

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	18	7.7	6.5	4	20	150	3	267	32	180	16.5	34	21	4	32	1.18	2.52
Someshwar	35	7.2	4.6	28	24	18	52	367	49	235	29	41	23	7	38	1.98	0.49
Anandwali	34	7.94	5.7	6.25	16	17	46	238	46	192	23	40	20	4.38	28.6	1.93	0.484
Victoria Bridge	35	7.2	4.6	28	24	18	52	367	49	232	29	41	23	7	38	1.98	0.49
Ramkund	34	6.9	7.2	8.5	18.5	16	46	238	46	247	23	40	20	4.38	28.6	1.93	0.484
D/S of Nasik	35	7.9	7.1	6.5	17	25	52	367	49	231	29	41	23	7	38	1.98	0.49

Month & Year:Sep-07

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	32	8	7	2	24	275	40	367	24	122	26	9.5	34	21	21	0.55	1.1

Someshwar	29	8.06	6.51	3	44	2	56	260	29	146	29	7.5	40	23.34	28	0.558	2.45
Anandwali	31	8.03	3.5	27	36	7	29	347	37	134	21	14.25	46	24	29	0.45	1.22
Victoria Bridge	34	6.1	6.2	22	39	9	32	422	41	102	27	25	51	19	42	0.49	2.9
Ramkund	28	7	6.9	8	21	35	25	209	15	105	25.5	39	36	13.13	26.8	0.542	2.19
D/S of Nasik	26	7.9	4.6	5	12.5	35	36	474	49	157	27	43	62	22	41	0.62	3.1

All Parameters are in mg/lit except PH, Temperature (^{o}C), and Turbidity (NTU), Conductivity (μs/cm).

Month & Year:Oct-07

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	30	7.6	4.8	8.5	24	175	21	159	1.5	129	27	8.5	50	38	4.82	0.04	0.77
Someshwar	27	8.4	7.6	5.5	30	120	27	221	1.05	196	21	6.75	82	38	12.2	0.8	0.41
Anandwali	32	8.08	5.7	6	25	160	26	390	2	272	31	12.25	105.2	54.4	42	0.8	0.89
Victoria Bridge	35	8.35	5	7	29	280	32	217	3.5	367	71	20	170	110	32.5	0.63	1.65
Ramkund	29	7.9	4.6	5	12.5	25	52	361	4.85	505	77	29	141	75	15.6	0.09	1.01
D/S of Nasik	23	6.9	7.2	8.5	18.5	16	59	378	6.5	565	112	36	147	73	19.6	0.224	0.96

Month & Year:Nov-07

Parameters	Temp	PH	DO	BOD	COD	Total Coliform	Turbidity NTU	TDS	SS	Conductivity	Chlorides	Sodium	Calcium	Magnesium	Sulphate	Phosphates	Nitrate
Gangapur Dam	31	7.5	7	4	24	110	45	165	0.41	176	17	25	92	34	3.28	0.015	0.15
Someshwar	25	7.99	7.4	5.9	19	126	51	149	0.82	242	19	5	80	46	27	0.5	0.9
Anandwali	30	7.91	5.8	7.3	21	127	36	139	1.3	297	37	8.5	81.2	45.8	23	0.14	1.93
Victoria Bridge	31	8.3	4.7	7.6	33	191	26	221	1.4	276	62	9.5	122	69	25	0.21	2.23
Ramkund	24	7.5	5.2	15	27	251	41	156	1.3	271	93	16.5	66	30	15.4	0	0.97
D/S of Nasik	21	7	6.9	8	21	35	51	597	6.4	605	129	35	148	66	16.6	0.04	0.99

All Parameters are in mg/lit except PH, Temperature (^{o}C), and Turbidity (NTU), Conductivity (μs/cm).

SOLID WASTE MANAGEMENT AT NASIK

MUNICIPAL SOLID WASTE TREATMENT PLANT AT NASIK CITY

WASTE STORAGE YARD

WASTE FEEDING TO 1ST STAGE SEGREGATION

2ND STAGE SEGREGATION (35MM & 16MM SIEVE)

COMPOST AS MANURE FOR REUSE

BIO-MEDICAL TREATMENT PLANT AT NASIK, MAHARASHTRA

MANUAL SEGREGATION OF BMW

BIO-MEDICAL WASTE

INCINERATOR

AUTOCLAVE

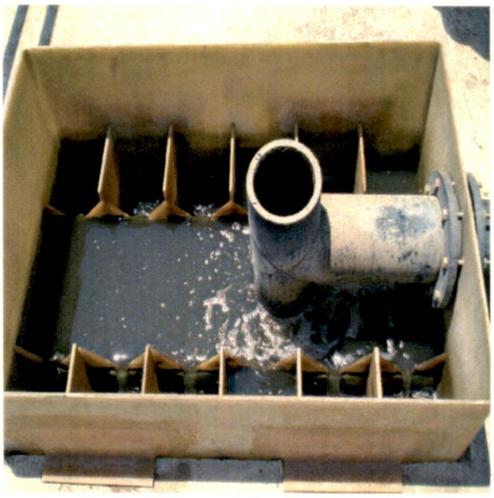
CHIMNEY

PHOTOGRAPHS OF 78 MLD WASTEWATER TREATMENT PLANT (UASB) AT NASIK

(1)

(2)

(3)



(4)

(5)

(6)

PHOTOGRAPHS OF 7.5 MLD ACTIVATED SLUDGE PROCESS (ASP) AT NASIK

(1)

(2)

(3)

(4)

(5)

(6)

78 MLD UASB SEWAGE TREATMENT PLANT AT TAPOWAN NASIK

DISTRIBUTION BOX

UASB REACTOR

FINAL POLISHING POND

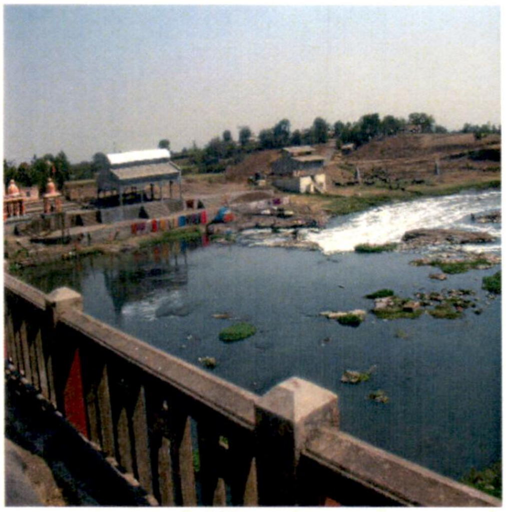
CONSERVATION MEASURES AT VARIOUS STRETCHES OF GODAVARI RIVER

ACTIVITIES AT VARIOUS SAMPLING LOCATIONS OF GODAVARI RIVER

PHOTOGRAPHS OF SAMPLING LOCATIONS AT GODAVARI RIVER

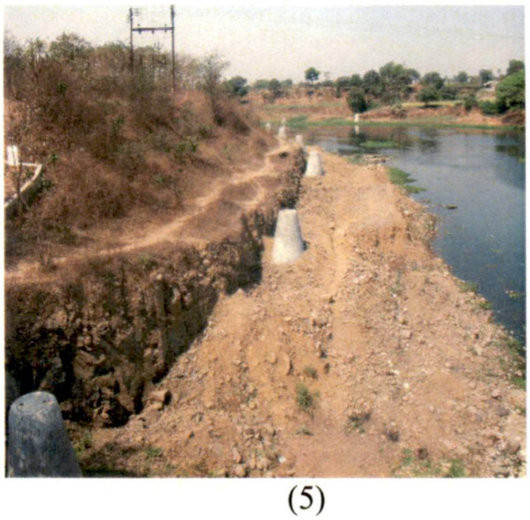
(1)

(2)



(3)

(4)



(5)

CHAPTER-5

RESULTS AND DISCUSSIONS

5.1 GENERAL

The River Godavari has been monitored for certain physico-chemical and bacteriological parameters namely temperature, pH, turbidity, specific conductivity, total solids, suspended solids, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, nitrate, phosphate, total coliform and faecal coliform from October 2007 to April 2008, also the available data from MPCB office and CPCB websites are referred as a secondary data. The river received domestic sewage when it enters the Nasik city. The river water quality changes while passing through the city towards downstream.

5.2 WATER QUALITY PARAMETERS

5.2.1 Temperature

The temperature values were recorded at site during the time of sample collection. The recorded water temperature of the Godavari River varies from station to station ranges from 18^0C to 37^0C as observed in primary data as well as secondary data shown in table. Moreover, the seasonal variation of temperature is also observed from secondary data. The temperature is one of the important factors for the survival of the aquatic life. Even 1^0C temperature rise in water may affect the aquatic organisms.

5.2.2 pH

The present analysis shows that the water of Godavari River is slightly alkaline. The pH value ranges from 6.5 to 8.49 throughout the stretch. All the values observed within the CPCB limits of the selected stretch which is 6.5 to 8.5.

5.2.3 Dissolved Oxygen (DO)

The concentration of DO is one of the most important indices of purity of river water. The concentration of DO in water represents the nature of organic matter present, the present analysis shows that the DO concentrations are within the range of 1.to7.90 mg/l. Generally, the DO value increases with the decrease in temperature.

5.2.4 Biochemical Oxygen Demand (BOD)

BOD approximates the amount of oxidisable organic matter in water. In the present study, the BOD values are found to be increasing gradually towards downstream part of the river. The BOD values were found within the range of 3.0 mg/l to 59.0 mg/. The increases of BOD toward the d/s stretch because of the city wastewater having high BOD (range 30mg/l to 75mg/l) are discharged into the river. Average BOD values at all the sampling stations are higher than 3mg/l.

5.2.5 Chemical Oxygen Demand (COD)

It is observed that the COD values are higher than the BOD values at all sampling stations. The COD values are within the range 12 mg/l to 76 mg/l. It is observed that COD values increases gradually from upstream to the downstream of the river from secondary data as well as primary data.

5.2.6 Turbidity

The guide value set for drinking water by WHO is 5 NTU. Low turbidity means greater penetration of light resulting in better photosynthetic activity in river and leading to better water quality. It is observed from data turbidity value varies from 3 to 59 NTU. CPCB has not specified any limit for turbidity thus, river water is suitable for recreational purpose, bathing and washing clothes etc. as far as turbidity is concerned.

5.2.7 Total Suspended Solids (TSS).

Total Suspended Solids (TSS). Values observed from 149 mg/l to 597 mg/l. More suspended solids possess more turbidity. Due to less photosynthesis and low DO, water in downstream stretches may have high TSS values.

5.2.8 Total Coliform

The presence of coliform is an important indication of the degree of health risk associated with use of river water for different purposes. CPCB has prescribed maximum value for MPN of 500/100ml while IS 2296 – 1974 has specified a much higher value of 5000/100ml. The observed values of total coliform ranges from 4 to 288

5.2.9 Heavy Metal

The water samples from various sampling stations were tested for heavy metals. The observed values are shown in the various tables of primary and secondary data. From the results it is observed that, all the heavy metals are within the permissible limit.

5.3 NSF WQI FOR STUDY STRETCH

There are various water quality indices available in the literature as already discussed in Chapter-2 and Chapter-3. NSFWQI is the most commonly employed and easy to use index software. In this present study, NSFWQI has been selected for assessment of the river water quality because of its versatility and on line software availability on internet.

5.3.1 NSF WQI

NSF WQI have been calculated for Dec'07 and Feb'08 for primary data and from the year 2002 to the year 2007 for secondary data are shown in Table 5.1 and Table 5.2 and also it shows on enclosed graphs namely NSFWQI Graph No.1,2,3 and Godavari River NSFWQI maps for River water quality. Higher value of the index indicates better water quality. In the present study, all the nine variables have been used to calculate the final index. for this report, when data for less than the nine variables is available, the index is calculated by summing up the sub index values of the variables present and dividing it by the sum of their weights. When all the available variables are considered, the index values have stayed more or less in the "bad" and "medium" categories. Upon removal of faecal coliform only, the index values increase considerably. Though, the values remain in the "medium" category for all sampling locations at all times, a marked increase can be observed. Similarly, when dissolved oxygen is removed, there is an obvious improvement in the index values. Dissolved oxygen has been given the highest weightage (0.17), but the variation after its removal is found to be less than that of faecal coliform in many of the locations. BOD has been given a weightage of only 0.10, but its removal also shows an appreciable variation, which proves that it is a critical pollutant variable. When the pollutant variables are removed in combination, the index values further increase to indicate improved water quality. When the combination of faecal coliform and dissolved oxygen is removed, there is a big increase from the original index value. The other combinations, i.e. faecal coliform – BOD and dissolved oxygen – BOD, also show appreciable increase from the original value, but less than that of the faecal coliform – dissolved oxygen combination. When all three pollutant variables are removed, the index value shoots up to the "good" category, even touching the "excellent" that is NSFWQI observed between 85 to 92 at some points. This is a clear indication that these three variables are very important for a river monitoring programme. They are the main pollutants in the Godavari River. Faecal coliform comes from the direct discharge of sewage from the latrines on the river banks and also from open defecation mainly at downstream of the river. Low dissolved oxygen levels and high BOD are due to the solid and other waste dumped into the river

Calculations of NSFWQI of various water quality parameters are given in below.

Table 5.1: Sample Calculations of NSFWQI for River Godavari at Nasik

Year 2002 NSFWQI Sample Calculation for secondary Data

Sampling Location	Parameter	Results	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
Gangapur Dam	Dissolved Oxygen	6.34	% sat	5	0.17	36
	Faecal Coliform	218.3	MPN/100ml	37	0.15	
	pH	7.86		88	0.12	
	BOD	5.9	mg/L	51	0.10	
	Nitrates		mg/L		0.10	
	Phosphates		mg/L		0.10	
	Temperature	24	°C	17	0.10	
	Turbidity		NTU		0.08	
	Total Solids		Mg/L		0.08	

December 2007 NSFWQI Sample Calculation for Primary Data

Sampling Location	Parameter	Results	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
Kushawart	Dissolved Oxygen	5.558	% sat	5	0.17	69
	Faecal Coliform	223.83	MPN/100ml	34	0.15	
	pH	7.11		90	0.12	
	BOD	8.69	mg/L	71	0.10	
	Nitrates		mg/L		0.10	
	Phosphates		mg/L		0.10	
	Temperature	27	°C	13	0.10	
	Turbidity	1.0	NTU	96	0.08	
	Total Solids		Mg/L		0.08	

February 2008 **NSFWQI Sample Calculation for Primary Data**

Sampling Location	Parameter	Results	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
Gangapur Dam	Dissolved Oxygen	6.8	% sat	5	0.17	57
	Faecal Coliform	78	MPN/100ml	47	0.15	
	pH	8.1		84	0.12	
	BOD	5.1	mg/L	55	0.10	
	Nitrates	0.23	mg/L	97	0.10	
	Phosphates	0.011	mg/L	100	0.10	
	Temperature	29	°C	11	0.10	
	Turbidity	22	NTU	59	0.08	
	Total Solids	181	Mg/L	75	0.08	

Table 5.2 NSF Water Quality Index for primary data

Sr No	Sampling Locations	DEC - 2007	FEB - 2008
1	Kushawart	69	64
2	Gangapur Dam	56	57
3	Someshwar	54	55
4	Anandwali	52	51
5	Victoria Bridge	52	51
6	Ramkund	55	52
7	Goda Kapila Sangam	42	41
8	Tapowan or D/S of Nasik	48	47
9	Dasak Village	52	54
10	Saikheda Village	54	61

Table 5.3 NSF Water Quality Index for Secondary data

Sr Nos.	Sampling Locations	Year					
		2002	2003	2004	2005	2006	2007
1	Kushawart	40	42	44	45	56	52
2	Gangapur Dam	36	38	40	42	49	57
3	Someshwar	35	36	38	40	48	53
4	Anandwali	34	35	37	39	46	44
5	Victoria Bridge	33	32	33	32	47	52
6	Ramkund	35	34	40	40	44	51
7	Goda Kapila sangam	-	31	-	-	-	39
8	Tapowan or D/Sof Nasik	34	35	40	41	45	47
9	Dasak Village	-	49	-	-	-	50
10	Saikheda Village	-	51	-	-	-	56

NSF Water Quality Indices

The water quality indexes of the Godavari River for the various sampling stations are tabulated in table 5.3 to ascertain the water quality at the respective stations.

Table: 5.4 Water quality index in the selected study stretch

Sr. No.	Sampling stations	Year 2003			Year 2007			Dec. 2007			Feb. 2008		
		DW	IV	C	DW	IV	C	DW	IV	C	DW	IV	C
1	SS_0	B	42	O	M	52	Y	M	69	Y	M	64	Y
2	SS_1	B	38	O	M	57	Y	M	56	Y	M	57	Y
3	SS_2	B	36	O	M	53	Y	M	54	Y	M	55	Y
4	SS_3	B	35	O	B	44	O	M	52	Y	M	51	Y
5	SS_4	B	32	O	M	52	Y	M	52	Y	M	51	Y
6	SS_5	B	34	O	M	51	Y	M	55	Y	M	52	Y
7	SS_6	B	31	O	B	39	O	B	42	O	B	41	O
8	SS_7	B	35	O	B	47	O	B	48	O	B	47	O
9	SS_8	B	49	O	B	50	O	M	52	Y	M	54	Y
10	SS_9	M	51	Y	M	56	Y	M	54	Y	M	61	Y

DW = Descriptor words,	**IV = Index value,**	**C = Colour,**
VB = Very bad,	0-25	R = Red,
B = Bad,	26-50	O = Orange,
M = Medium,	51-70	Y = Yellow,
G = Good,	71-90	G = Green,
E = Excellent,	91-100	B = Blue

From the above tables it is observed that, it can seen that the NSFWQI is between 31 to 51 for the year 2003 and index values between 39 to 57 for the year 2007 for secondary data where as index values varies from 42 to 69 for primary data at selected study stretch at sampling location no 8 index values for all the months is observed less as compared to next two sampling locations reason is that the discharge/effluent of 78 MLD sewage treatment plant confluence to this point and hence because of this the index has increased to indicating the impact of STP on the river water quality. The quality of water before STP also shows improvement because, after the year 2003 waste water from the city which was discharging in the river has been diverted to the STP.

Primary as well as secondary data clearly indicates that river water quality degrades while its passage through the city. The index value decreases from station 3 towards downstream and attains lowest value at station 7 and index increases from sampling station 7 to sampling station 10 in the year 2003. The index values increases in the year 2007 at all sampling locations as compared to the year 2003 the values of NSFWQI between 26 to 50 indicates, the river water quality as "Bad" in the descriptive words and denotes colour orange and the values of NSFWQI between 51 to 70 indicates, the river water quality as "Medium" in the descriptive words and denotes colour Yellow as shown in the enclosed river water quality maps and graphs. Only these two colors and index ranges are observed in the selected study stretch that means water quality was bad during the year 2003 and it gradually increasing towards medium till today because of the several conservation measures are taken by the Nasik Municipal Corporation which are discussed in para 5.4.1.

5.4 WATER QUALITY MANAGEMENT OF GODAVARI RIVER

As discussed earlier, the main pollutants in River Godavari are faecal coliform and organic wastes. The water quality management measures to be adopted should target the removal of these two main pollutants first. The main source of faecal coliform is waste water coming into the river from the numerous drains and the direct sewage generated near the river banks. The lack of proper management of municipal solid waste in some areas of the city has led to its being dumped indiscriminately into drains and the river itself. Same of water quality techniques are suggested to tackle the main sources of pollution of the River Godavari e.g. Sewage treatment, effluent treatment plants for industrial waste water, solid waste treatment and disposal plants, Low Cost Sanitation, Electric and Improved Crematoria, Bathing Ghats / River Front Developments, Plantation and Land Scaping, Biomedical waste treatment plant, Decentralized sewage treatment plants etc.

The key to the water problems is control by water quality management planning and proper implementation of various pollution control acts, environmental laws enforcement of national standards, the licensing and policing of discharges, by following approved procedures in agriculture, and by creating environmental awareness on the part of the public with proper control measures.

5.4.1 Management Measure Suggested To Control Water Quality of Godavari River

5.4.1.1 Sewage Treatment

Need for wastewater treatment

The purpose of wastewater treatment is to remove the organic and inorganic solids. The organic solids are decomposed by microorganisms and inorganic solids that are inert are removed by sedimentation. The treatment of sewage consists of primary, secondary and tertiary treatment. The primary treatment units are screen chamber, grit chamber, and primary settling tank. The secondary treatment units are aeration tank and secondary settling tank. The tertiary treatment units are rapid sand filtration or slow sand filtration and nutrient removal by various methods. The domestic sewage is the major source of pollution for surface as well as ground water. The water becomes unfit for various uses and causing waterborne diseases. The discharge of untreated wastewater into the aquatic environment is the main cause of diarrhea diseases. As the quantity of wastewater discharged into the rivers/water bodies exceeds the self cleansing capacity of rivers the dissolved oxygen in the water reduces and the aquatic life will starts disappearing. As the rivers are the major sources of drinking water needs, the treatment of wastewater becomes necessary.

The waste water treatment systems are very essential for the following reasons

To reduce human disease and to promote public health,

To eliminate gross water pollution effects and

To achieve levels of water quality that allows native marine organisms / aquatic life to return to normal growth patterns and allows full human recreational use.

Removal of Suspended Solids by Clarification (In Sedimentation Tank) & Decomposition (By providing Suitable conditions for bacteria)

Removal of Organics by Decomposition (By providing Suitable conditions for bacteria) & Provide conditions for separation of the wastewater from the Bacteria.

Removal of Residual bacteria present in separated wastewater by adding powerful oxidants such as Chlorine.

DESIGN PERIOD:

The sewage treatment system is normally designed to meet the requirements for a period of 30 years or more after the completion of construction activities. The system should not be under-loaded in the initial years nor be over-loaded in the dying stages. A provision has also to be made for installation of civil structures at any later date depending upon the requirement.

POPULATION AND WATER DEMAND OF NASIK CITY:

Present population of Nasik City is 15 Lacks and the present treatment system is for 60% of the total waste water generated, for remaining 40% sewage one more sewage treatment plant of 52 MLD capacities UASB technology work is in progress and other two more STPS are proposed. Existing treatment systems are UASB and ASP technology based out of three two are 78 MLD and 22 MLD of UASB technology based an done is 7.5 MLD Activated Sludge Process technology based. One more STP of 52 MLD UASB based work is in progress. All these existing and proposed sewage treatment plants are as per national River Conservation Plan (NRCP) and hence the activities of NRCP are taken in to consideration.

The manual of water supply and treatment shows a water requirement of 135 lit/cap/day is sufficient for domestic use. Since in this project, the domestic water supply is only considered. The study done in the report of domestic water conservation has also mentioned that 135 lit/cap/day supply of water fulfills the public demand. According to IS 1171-1971 also, in India on an average the domestic consumption of water under normal conditions is 135 lit/cap/day. Hence the figure is chosen.

Hence by considering losses in treatment plant and distribution system = 15 % and 5 % for non domestic supply, water treatment plants are to be designed for the capacity of

= (1500000 X 135 X1.20)/ 106

= 202.5 MLD

Presently three treatment plants are working properly with a capacity of (78+22+7.5) MLD, that means only 107.5 MLD wastewater is treated by Nasik Municipal Corporation and remaining 95 MLD (202.5 – 107.5 = 95 MLD) waste water is directly discharged in to Godawari River through various domestic wastewater Nallas which causes river pollution.

Nasik city has grown in a haphazard manner with absolutely no planning at all. To plan and lay a sewer system in the city is an impossible task as of now. The only way to stop the waste water from entering the river is to intercept all the drains and tributaries at their point of confluence with the river and treat and dispose it properly through various treatment plants installed by Nasik Municipal Corporation. Present population of Nasik city is more than 15 Lacs and the 60% waste water is treated through various treatment plants like 78 MLD UASB based plant at Tapowan Nasik and 7.5 MLD ASP based treatment plant at panchak village, Nasik and 22 MLD plant of UASB based at chehadi village additional 52 MLD UASB sewage treatment plant work is in progress at Tapowan and the same will be completed in the next year. After completing this plant additional 10 % waste water will be treated, even though there is scope for remaining 30% waste water treatment for which I will suggest two more decentralized sewage treatment plants.

5.4.1.2 Municipal Solid Waste Management

Presently solid waste collected by the Nasik Corporation from major part of the city, the focus should be require on management of solid waste in the adjoining areas of the city. The most effective method to manage waste in these semi-urban areas is by localizing the collection and treatment of the waste, i.e. waste generated within one locality is collected and treated within that locality itself. In the commercial areas, it shall be the responsibility of the traders to collect their own waste and store it at sites designated by the Nasik Municipal Corporation for collection or transport it themselves to the treatment sites. The cheapest methods of waste treatment are heap composting and vermin composting. The organic fertilizer produced from composting can be sold off to generate money.

Finally, solid waste management depends on the people's attitude and co-operation. If the entire community shows willingness to mange their waste, there is nothing that can stop them from doing it. To create this willingness, it takes a lot of hard work on the part of the experts to educate and spread awareness about solid waste and its management required by the Nasik Municipal Corporation and various government authorities.

5.4.1.3 Public Participation

In any conservation project, the role to be played by the public is of utmost importance. There are many stakeholders involved with the River Godavari. Various Government Departments, like the Department of Urban Affairs, the Nasik Municipal Corporation, the Maharashtra State Electricity Board, the Maharashtra State Pollution Control Board, the Agriculture Department, the Tourism Department, etc, have a direct role to play with regards to the river. The main stakeholders are, of course, the public. A clean River Godavari means better living environment, clean water to use and even recreation.

The only source of pollution in the river is from anthropogenic activities. Stopping these activities will be the only solution to restore the river to its pristine state. The attitude of the people should change completely. They should manage their wastes in a proper manner instead of directly discharging or dumping them into the river. The Government departments can only create awareness among the public about the river and its conservation. It is finally only up to the people to see that the river is clean. Several NGOs and Self Help Groups are doing a lot of work in spreading awareness and in trying to clean up the River Godavari. These groups should be encouraged to carry on with their work by the government authorities.

Finally, the Government with its experts and man-power should start an extensive awareness campaign about cleaning the River Godavari. The high-level meetings and committees should now start their work in the field and ensure that the people are made aware about the danger of our losing a natural resource and how we can join hands together to restore it back to an acceptable level, if not to its original pristine condition.

5.4.2 CONSERVATION MEASURES ALREADY TAKEN BY THE NASIK CORPORATION

5.4.2.1 Municipal Solid Waste Management

In the year 2001 municipal solid waste plant at pathardi, Nasik was installed by Nasik Municipal Corporation on BOOT basis. The capacity of the plant for treatment of solid waste is 300 MT/Day, but presently waste collected by the corporation is 250 MT/day from the city area only as the total population of Nasik Corporation is 15 Lacs but total solid waste generated is not collected and treated. The collection system is door to door on contract basis by tractor trolleys called as Ghanta Gadis. Segregation process on the site is done be 40-50 rag pickers manually. Three stage segregation with composting process is working effectively on 23 acres land area, out of that 7 acre area is for land filling. Sufficient tree plantation is done by the corporation in the premises. From this process final product compost is manufactured 20 MT/day which is sold to farmers for use as a manure. Some photographs of the plant are enclosed.

5.4.2.2 Conservation Measures taken for Bio-Medical Waste

The daily quantity of bio- medical waste collected and treated presently is 1500 to 2000 kgs/day, almost all the major hospitals are attached to this common bio- medical facility run by water grace products on BOOT basis. Collection of BMW waste in Biodegradable & incinerable bags. Waste collected in specially designed vehicles. The major units of the treatment process in this plant are

i) Incineration

ii) Autoclaving

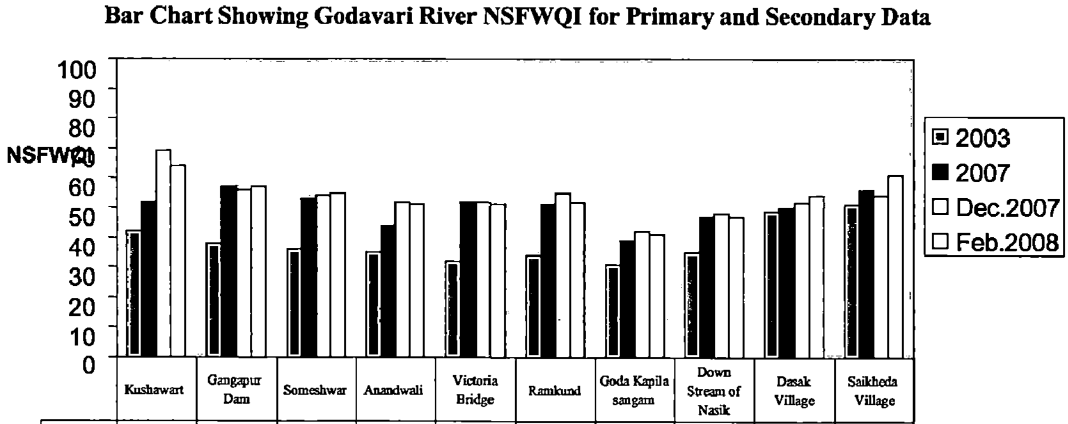
iii) Shredding.

Some photographs of the BMW plant are enclosed.

5.4.2.3 Sewage Treatment

At Tapowan 78 MLD sewage treatment plant is installed in the year 2003 by the Nasik Corporation during the Kumbhmela. Presently the plant is working at full capacity; all the results are within limits as per CPCB norms. The plant is based on UASB technology. Foaming problems are observed in final polishing pond at site because of the more washing activities and detergent use. New CCT (Chlorine Contact Tank) Unit installed in last month to reduce faecal count, Aeration outlet channel construction work was in progress to reduce foaming, with the help of these channels water will discharge smoothly in the final polishing ponds instead of pressurized disposal. Incoming flow observed is as per plant capacity. In addition of that 7.5 MLD ASP based treatment plant at panchak village, Nasik and 22 MLD plant of UASB based at chehadi village were also working satisfactorily. New proposed 52 MLD UASB technology based sewage treatment plant construction work is in progress.

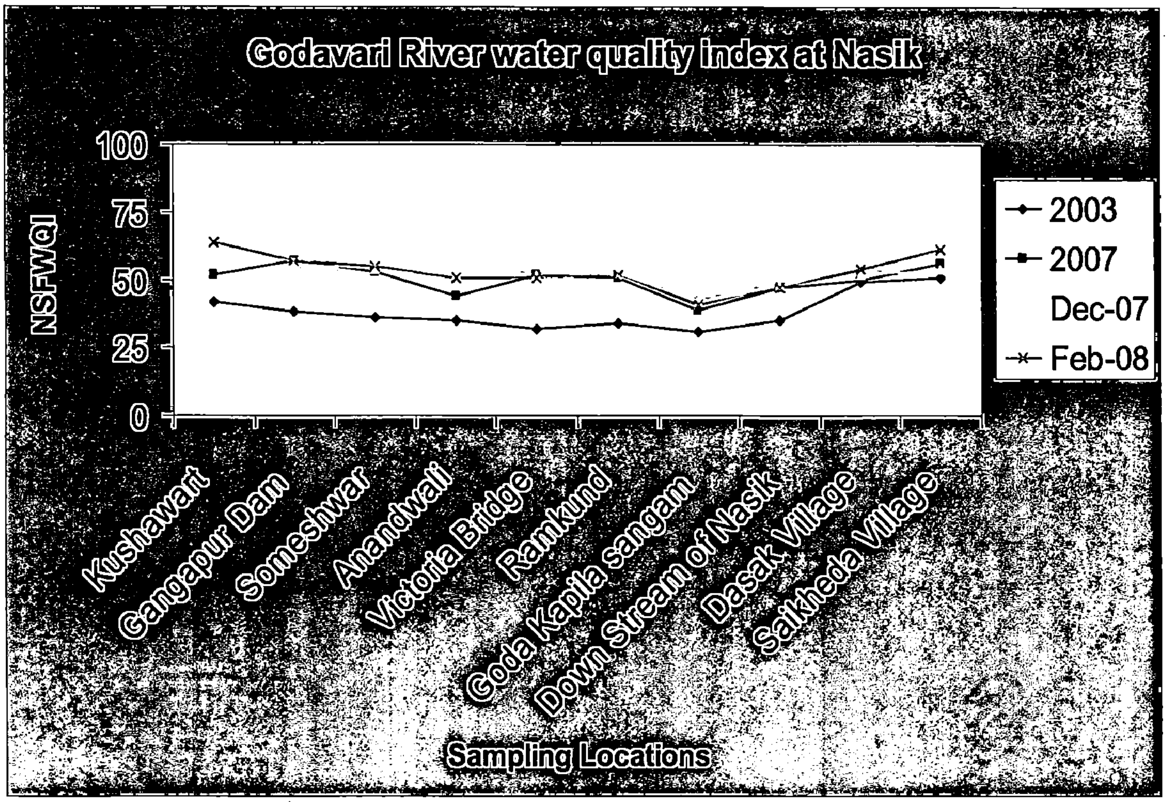
As already discussed in para 5.3 Bar chart and Line diagram Graghs for the primary and secondary data enclosed on page nos127 and 128 also different maps of study stretch of Godavari River for the year 2003, 2007 and for the month February are enclosed at page nos. 129 – 131. on the basis of these graphs some conclusions are drawn in chapter 6.



	Kushawart	Gangapur Dam	Someshwar	Anandwali	Victoria Bridge	Ramkund	Goda Kapila sangam	Down Stream of Nasik	Dasak Village	Saikheda Village
2003	42	38	36	35	32	34	31	35	49	51
2007	52	57	53	44	52	51	39	47	50	56
Dec.2007	69	56	54	52	52	55	42	48	52	54
Feb.2008	64	57	55	51	51	52	41	47	54	61

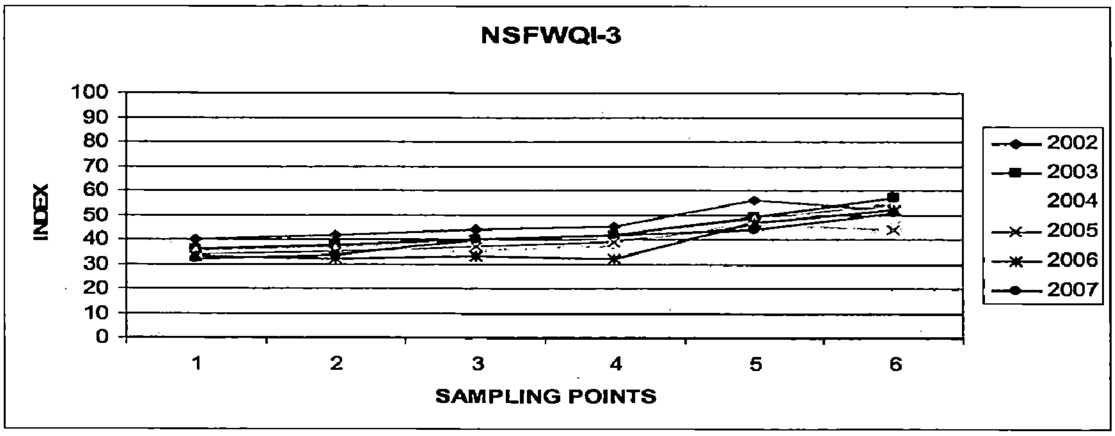
Sampling Locations

Graph no. 1 - NSFWQI 1

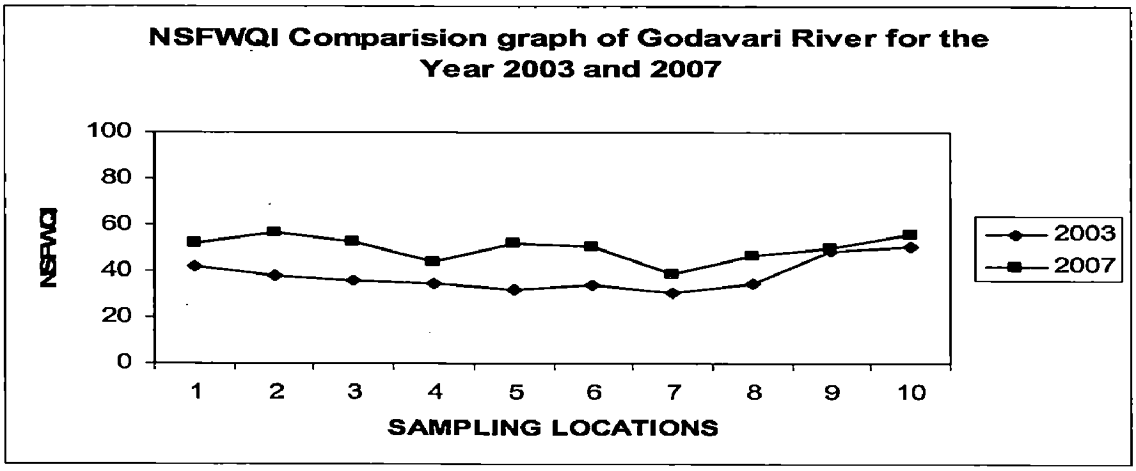


Graph no. 2 – NSFWQI 2

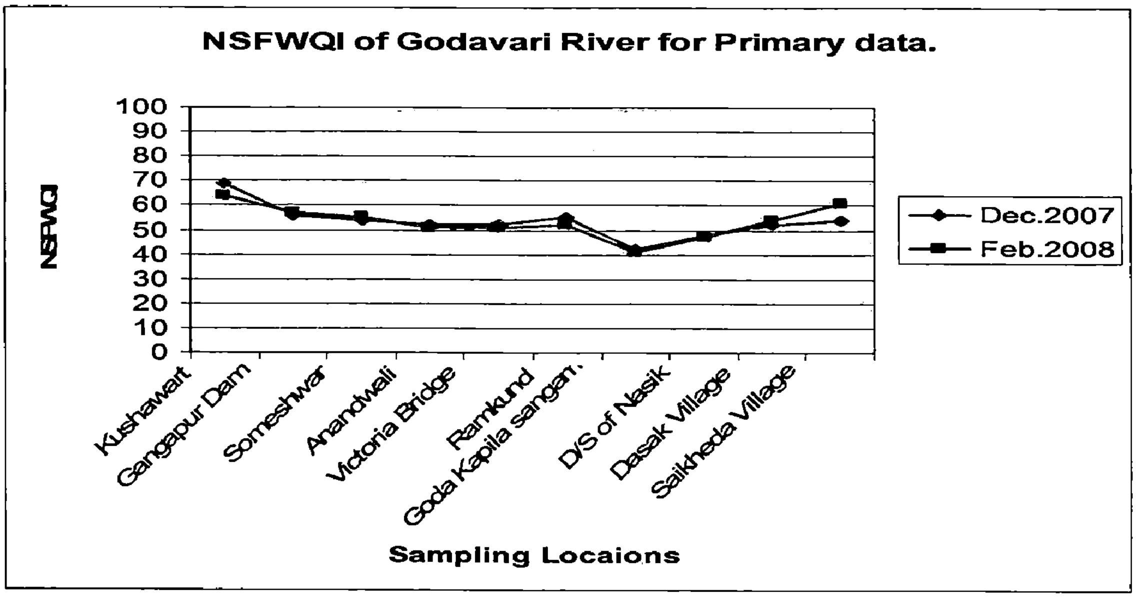
NSFWQI of Godavari River for Primary Data



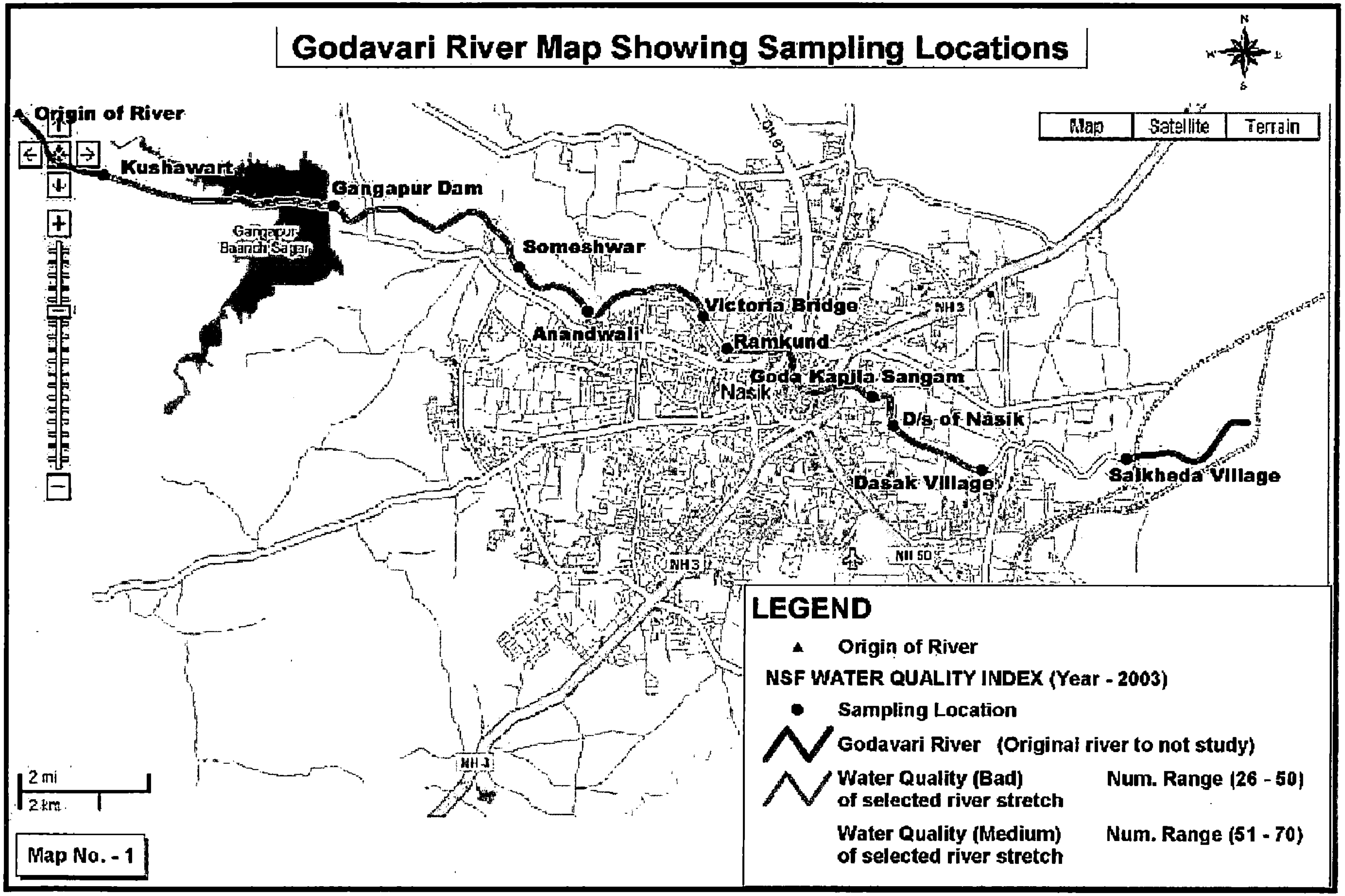
Graph no. 3 – NSFWQI 3

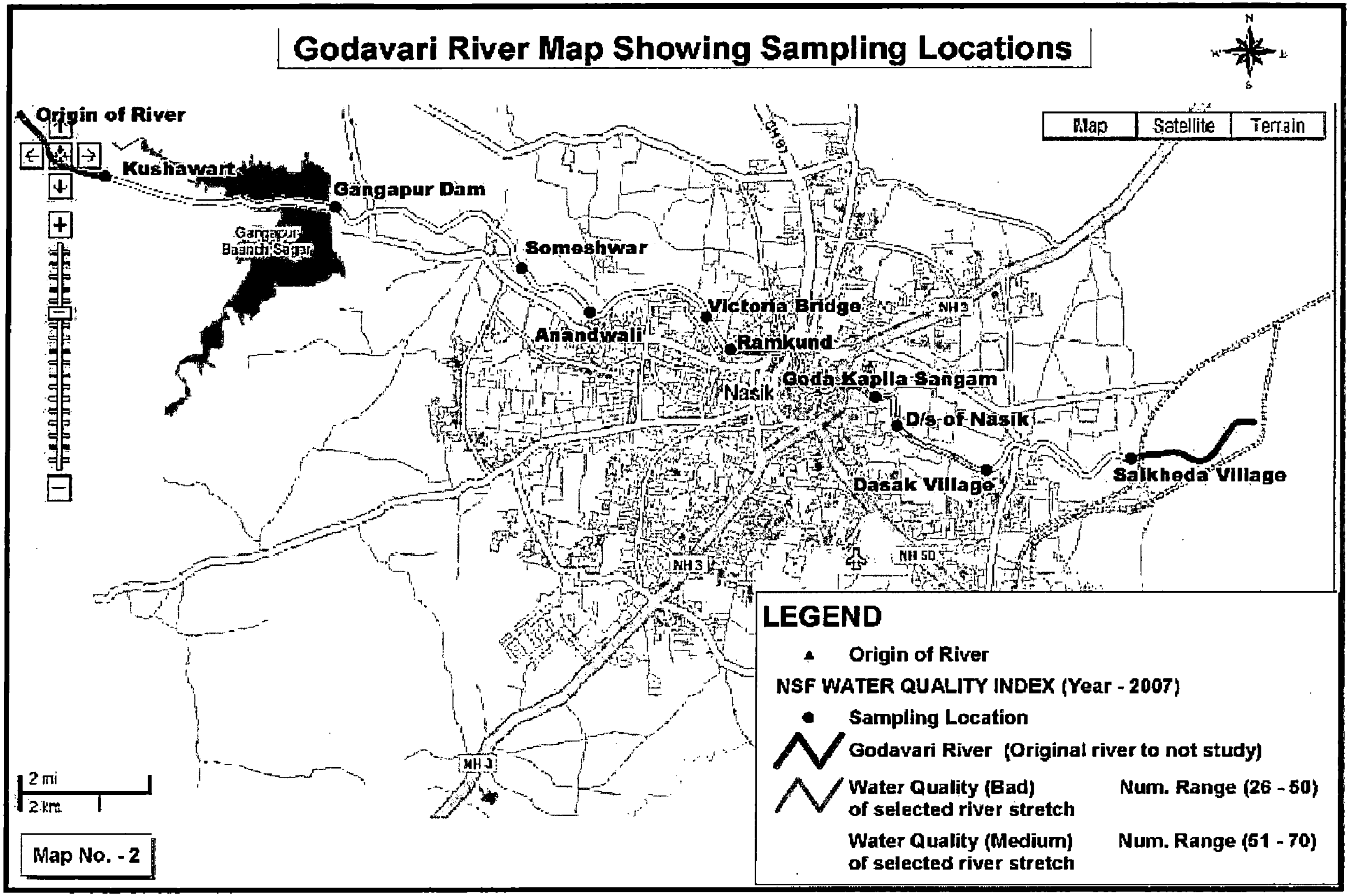


Graph no. 4 – NSFWQI 4

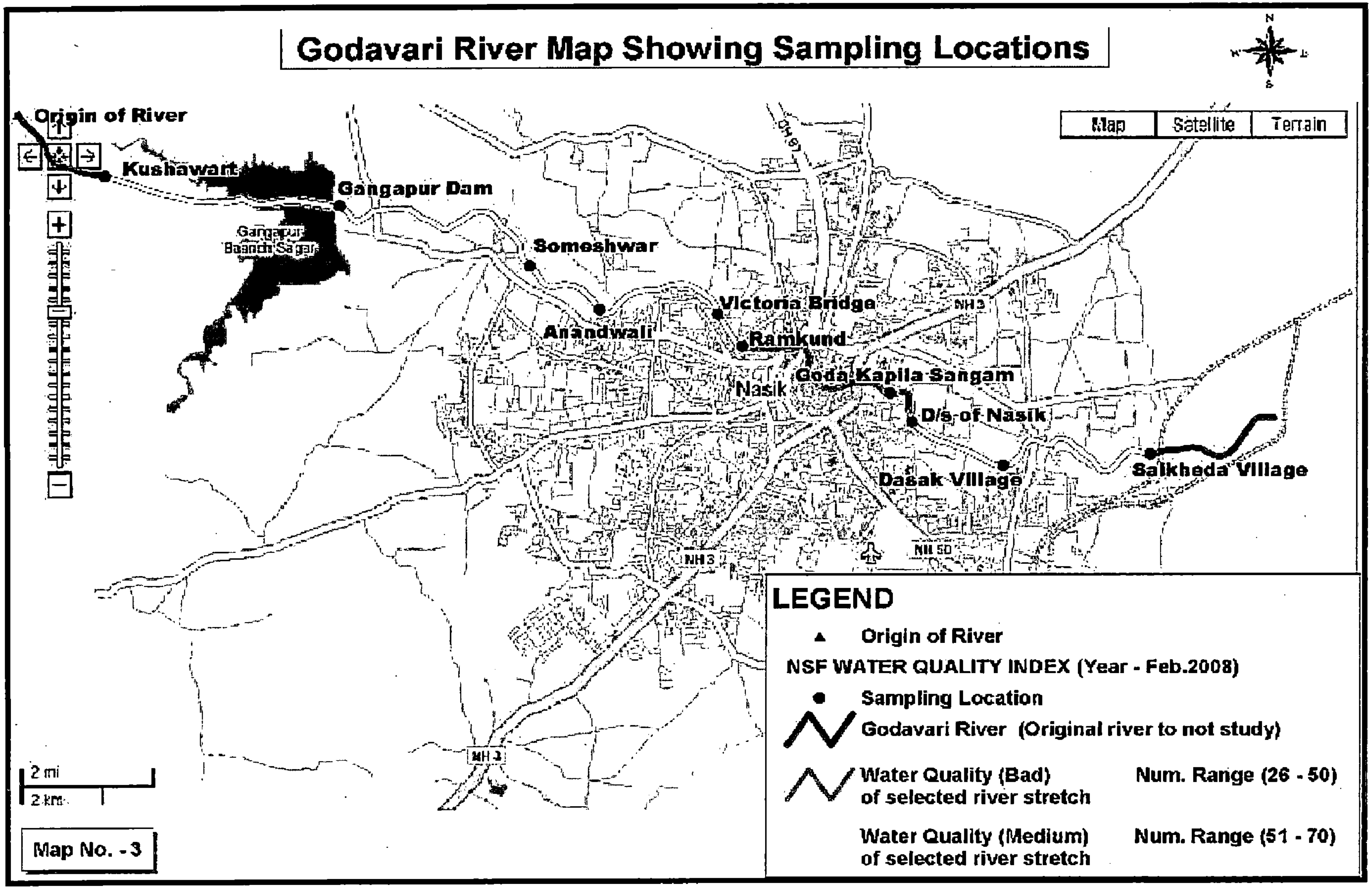


Graph no. 5 – NSFWQI 5


Godavari River Map Showing Sampling Locations
Origin of River
Kushawart
Gangapur Dam
Gangapur Baandh Sagar
Someshwar
Anandwali
Victoria Bridge
Ramkund
Goda Kapila Sangam
Nasik
D/s of Nasik
Dasak Village
Saikheda Village
NH3
NH 50
Map
Satellite
Terrain
2 mi
2 km
LEGEND
Origin of River
NSF WATER QUALITY INDEX (Year - 2003)
Sampling Location
Godavari River (Original river to not study)
Water Quality (Bad) of selected river stretch
Num. Range (26 - 50)
Water Quality (Medium) of selected river stretch
Num. Range (51 - 70)
Map No. - 1



Godavari River Map Showing Sampling Locations



Godavari River Map Showing Sampling Locations
Map
Satellite
Terrain
Origin of River
Kushawart
Gangapur Dam
Gangapur Baandh Sagar
Someshwar
Anandwali
Victoria Bridge
Ramkund
Nasik
Goda Kapila Sangam
D/s of Nasik
Dasak Village
Saikheda Village
NH3
NH 50
OH 97
2 mi
2 km
Map No. - 3
LEGEND
Origin of River
NSF WATER QUALITY INDEX (Year - Feb.2008)
Sampling Location
Godavari River (Original river to not study)
Water Quality (Bad) of selected river stretch
Num. Range (26 - 50)
Water Quality (Medium) of selected river stretch
Num. Range (51 - 70)

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

The NSFWQI is a versatile and flexible index software using this the calculated values are used to draw graphs like line diagram and bar chart and also a water quality profile of the Godavari River has been plotted for the year 2002 to the year 2007 and for primary data also through GIS. From the water quality profile of Godavari River, it is observed that there is very little variation in the water quality throughout the study stretch of the river. The NSFWQI values remain in the "bad" and "medium" categories throughout the selected study stretch. This evidently shows that the river is in a very bad state of pollution and its entire stretch has been affected and the same is increasing towards medium and good quality from the year 2003 to the year 2007. Therefore, the following important conclusions are drawn from the study.

1. Is observed from primary data table 5.2 that the water quality before Gangapur Dam is in the medium range but after water entering in to city it converts in to bad range at sampling location 7 and 8 indicates that the river is polluted due to effluents and sewage it receives from the various sources from Nasik city.

2. The BOD values reveal that the water quality of the Godavari River is of bad category range due to high content of organic matters in the water mainly at sampling locations 4, 7 and 8.

3. The water quality index such as NSFWQI is used to ascertain the water quality of the Godavari River. The NSFWQI indicates the water quality is in between bad and medium ranges at different locations for primary and secondary data at all sampling locations.

4. The NSFWQI reveal that the Godavari River is suffering from the high organic pollution problem due to sewage water it receives from the various sources mainly at downstream of the Nasik city.

5. The water contains high total coliform and faecal coliform which indicate the presence of pathogens in the river water.

6. Gangapur Dam is the second sampling station where river is almost pollution free and downstream is the eighth sampling station up to where it receives maximum pollution from the city.

7 Out of the various indices, NSFWQI is determined in this study. This shows that, water quality is bad and medium throughout the stretch as its value is between 26 to 50 and 51 to 70 for all locations.

Index values obtained by the NSFWQI have been put into water quality maps and graphs to show the changes in the water quality of the River Godavari. From these maps, it is observed that the water quality of the river has very less variation throughout the year. It remains polluted throughout the year and no more dilution has been observed during the monsoon months. This is mainly due to high faecal coliform counts and high loads of BOD and COD that the river carries.

Based on the results of water quality assessment of the River Godavari, it is observed that the overall water quality of the River Godavari is "bad" or "medium" as fact reflected at all the sampling locations. The NSFWQI observed between 26 to 50 and 51 to 70 indicates that the water quality of the Godavari River is between bad – medium range, further the results of the year 2003 and 2007 indicate the improvement in water quality at all locations because of the existing conservation measures being taken by the Nasik Municipal Corporation. Major stressor of pollution has been found as pollution due to sewage i.e. organic pollution with main contribution from faecal coliforms, BOD and reduced DO. The water quality maps prepared on the basis of NSFWQI have also indicated the same trend. These maps can be used to plan conservation measures for achieving the objectives. Existing conservations are three sewage treatment plants having capacity 78 MLD, 7.5 MLD and 22 MLD at Tapowan, Dasak and Takali respectively, solid waste treatment plant and bio- Medical waste treatment plant appear to be inadequate to improve the water quality due to substantial improved population.

In view of above two more sewage treatment plants recommended in addition to improvements in the areas namely municipal solid waste management, bio-medical waste management, plastic waste, slaughter house waste, e waste etc.

REFERENCES

1. Arceivala, S.J., "Waste Water Treatment for Pollution Control", 2nd Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi, 214-17, 2003.

2. APHA – AWWA – WPCF, "Standard methods for the examination of water and waste water", 19th Edition, Washington, D.C. 1995.

3. Bansil, P.C., "Water Management in India", Concept Publishing Company, New Delhi, 550-558, 2004.

4. Bhardwaj, R.M., "Status of Wastewater generation and Treatment in India", IWG-Env, International Work Session on Water Statistics, Vienna, 2005.

5. www.mpcb,mah.nic.in.

6. www.cpcb.nic.in/mar95ii.htm

7. Chaudhari N. Water Quality Control., The Indian context central board for prevention and control of water pollution, New Delhi, 1982

8. Das, D.N., "Studies on the sources of pollution in Tunia river", M.Tech, Project report, AHEC IITR. Roorkee, 2005.

9. Mahajan, K.K., "Deteriorating Nation's rivers. In: ecology and pollution of Indian rivers" (Ed. RK Trivedy), Ashish Publishing house, New Delhi. 1-38, 1988.

10. www.sandec.ch/publications.

11. Cude, C.G., "Oregon Water Quality Index: A Tool for Evaluating Water Quality Management Effectiveness", Journal of the American Water Resources Association, 37 (1), 125-137, 2001

12. Central Public Health and Environmental Engineering Organisation, "Manual on Sewerage and Sewage Treatment (Second Edition)", 1993.

13. www.cpcb.nic.in/pcpdiv_plan4.htm

14 www.cpcb.nic.in

15 Joseph F. Malina, Design of Anaerobic Processes for the treatment of Industrial Microbiology and Municipal waste 7, 13-15 & 59-61.

16. Journal of Environmental Management. 73(3), 229-242, 2004.

17. www.iitr.ernet.in

18. Kumar N., "Pollution Studies on River Ramganga at Moradabad", M.E. Thesis, Environmental Engineering Section, Department of Civil Engineering, University of Roorkee, Roorkee, 1997.

19. The Times of India, New Delhi, "Survey Finds India Overusing its Groundwater Resources", 22nd March 2006.

20. Odum E.P, 'Fundamentals of Ecology', Natraj publisher, Dehradun, 1996.

21. www.environment .gov.au/water/quality

22 www.hydrologydatainfo.org

23. www.sciencedirect.com

24. NAS, Planning for Environmental Indices', A Report of Planning Committee on Environmental Indices, national Academy of Sciences, Washington D.C.1975.

25. www.bcn.boulder.co.us/basin/watershed/wqi_nsf.html

26. Ott, W.R., "Environmental Indices – Theory and Practice", Ann Arbor Science Publishers Inc., Michigan, 369-371, 1978.

27. Chapman, D., "Water Quality Assessments", 2nd Edition, E&FN SPON, London, 243-74, 1996.

28. Guidelines for Drinking Water Quality, 'Health Criteria and Other Supporting information', WHO, Geneva, 1, 1984,

29. Trivedi, R.R, "Research Methodology and System Analysis", Paper – IX, Indian Institute of Ecology and Environment, New Delhi -30, 28-40, 2000.

30 www.waterontheweb.org/under/waterquality/oxygen.html

31 Citizen report" The state of Indian's environmental centre for science and environment", New Delhi, India, 1982

32 www.glcf.umiacs.umd.edu/index.shtml

33 Central Pollution Control Board, "The Brahmaputra Basin", sub basin inventory of water pollution, Ministry of Environment & Forests, 31-39, 2000.

34 Mathur, R.P., "Water and waste water testing" (Laboratory Manual), 1st Edition, Nem Chand & Bros (Publishers), Roorkee, 1982.

35 Mc Carty, P.L.; Parkin, G.F. and Sawyer, C.N, "Chemistry for Environmental Engineering and Science" 5th Edition, Tata Mc Graw-Hill Publishing Company Limited, New Delhi, 2003.

36 Peavy, H.S; Row, D.R. and Tchobanoglous, G., "Environmental Engineering", International Edition, Mc Graw-Hill Book company, New Delhi, 14-110,1984.

37 Tchobanoglous, G. and Burton, F.L., "Waste Water Engineering", 3rd Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi, 12-14, 2003.

38 Thomann, R.V. and Mueller, J.A, "Principles of Surface Water Quality Modeling and Control" 1st Edition, Harper & Row Publishers, New York. 1987.

39. www.nashikcorporation.com

40. http://www.cpcb.nic.in/dstscontent.htm

41. Said, A., Stevens, D.K. and Sehlke, G., "Environmental Assessment – An Innovative Index for Evaluating Water Quality in Streams", Environmental Management, 34(3), 406-414, 2004.

42. www.water-research.net/watrqualindex/waterqualityindex.htm

43. Rajesh Baruah, M.Tech (CRL), AHEC, IIT Roorkee, Dissertation Report 'Study Of Impact of Domestic Sewage and Industrial Effluent on Water Quality of River Bharalu'2006.

44. Bantehsonglang Blahwar, M.Tech (CRL), AHEC, IIT Roorkee, Dissertation Report "Water quality assessment and conservation of Umkhrah River" 2006.

45 Dhwajendra Nath Das M.Tech (CRL), AHEC, IIT Roorkee, Dissertation Report "The Effect on Water of Tunia River Due To Pollution of the Industrialization and Urbanization" 2006.

46 Project Report on Godavari River Water Quality Analysis submitted by Kishor Dabhade for Manipal Sikkim University.2004

47 W.H.O., "Guideline for Drinking Water Quality, World Health Organization", Geneva 3: 121. , 1985.

48 Central Public Health and Environmental Engineering Organisation, "Manual on Municipal Solid Waste Management. (First Edition)", 2000

49 www.noah.dk/miljosk/vidya.pdf

50 www.pollutedplaces.org/region/south_asia/india/shillong.shtml

51 www.corvallis.k12.or.us/cvhs/bregard/fb/wqindex.htm