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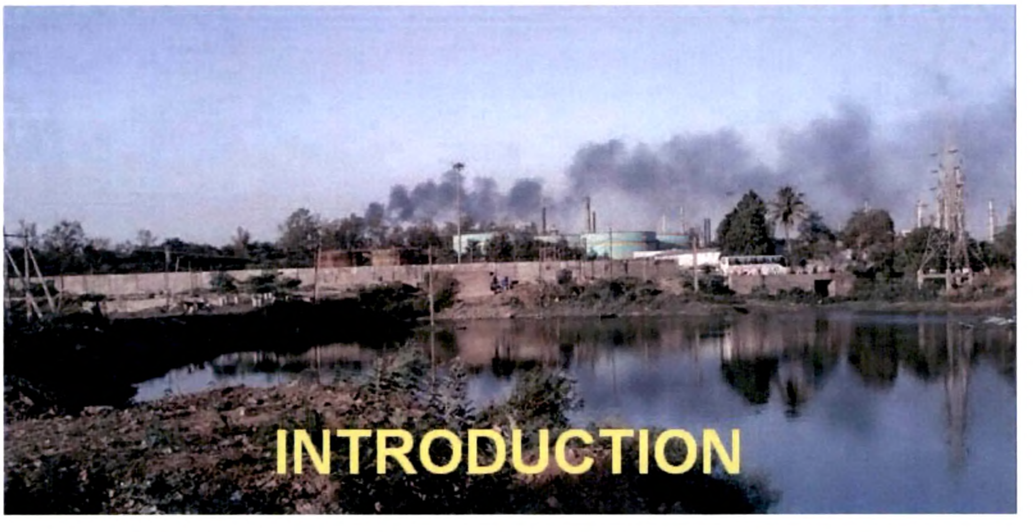

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CHAPTER 1: INTRODUCTION

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1.1. Status of Environmental Pollution

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Industrial and technological development have although led the world to advancement with an obvious impact on human's life style, they have their destructive effects also since the waste produced is harmful to the overall environment and hazardous to human health. However, the inventions and formulations of new chemicals are still continuing and a compound with different property is generated. The industries dispose these chemicals in different ways which includes; for liquid effluent, surface and sub surface runoff, direct release into the pond, stream, river or sea, and even direct disposal into the ground water. The gaseous toxicants are released directly into the ambient environment. The solid waste is dumped into the ravines of river, as fill in for village ponds and as spread over the grazing or waste lands. Through these the toxicants pollute the soil and water bodies (Fig. 1). The research carried out during past several decades has identified potential hazardous chemicals, the duration and doses which can cause toxicity and also the concentrations which are permissible for release of pollutants into the environment. Different criteria have been developed for environment impact assessment of chemicals. The literature is piled up with the reports on experimental and epidemiological evidences of adverse effects of a chemical on different systems (USEPA, 1997; ATSDR, 1998; ATSDR, 2001). The pollution impacts on environment, in experimental animals and in humans, are reported the world over during past few decades (Colborn, 1995; Cooper and Kavlock, 1997; Jenkins et al., 2003; Harding et al., 2006). However, the production, uses and unauthorized disposal have not been regulated so far and thus describe a gloomy picture of the future environment. The criteria for permissible aquatic discharges were laid down decades ago, however, these are not strictly followed and untreated raw industrial waste is being poured into the ponds and lakes, streams, rivers, estuaries and oceans leading to constant threat of health hazard to a large population directly or indirectly. With exploding population and increasing industrialization, water pollution by agricultural, municipal and industrial sources has a major concern.

Aquatic pollution is referred as an alteration in the physical, chemical and biological characteristics of water that renders it unsuitable for its intended purpose. Two types of aquatic pollution sources exist; point sources and non point sources. Point sources of aquatic pollution occur when harmful substances are emitted directly into a water body. A non point source delivers pollutants indirectly from different sources through surface or sub surface runoff. An example of this type of water pollution is when agrochemical discharges from a field are carried into a pond or stream during monsoon in form of runoff which in turn affects aquatic life. Pollution arising from non point sources accounts for a majority of the contaminant in ponds and lakes, however, the tendency exists for monitoring and regulation of point source pollution. The pollution discharges and consequent impacts on various components of aquatic environment suggest necessity of integrated comprehensive studies (Fig. 2). The diagram is divided into two phases namely nodes (boxes) and chains (arrow) to indicate the source, the path and the sink or the target. The important sources (both qualitative and quantitative) and the targets are groundwater, surface water, soil and the biota. The air environment is of considerable significant but not equivalent to the water or soil components. The pollution inputs are shown to alter all these sources and lead to consequences that further alter other sources ultimately influencing the overall quality of the aquatic system resulting into an adverse effect on biota. Surface runoff which includes precipitation, agro-irrigational, industrial and domestic discharges is an important independent factor. The volume of individual constituent and their quality directly influence all the sources that may recharge the pond.

In an aquatic system, the rates at which the pollutants may manifest their action at the ecosystem level largely depend on various criteria (Fig. 3). From the concentration at the site of release (source) to the effect at the target is manipulated by rates of emission, transport and removal/accumulation. These depend on various biotic and abiotic variables. The accumulation within the ecosystem components and the biomagnification along the food chain is actually a long term consequence of pollution of the aquatic system.

The aquatic bodies are extensively polluted leading to impacts on abiotic and biotic components. A summary of important literature is presented in Table1. The pollutants alter the buffering potential of the system and thus various physicochemical characteristics are drastically changed. The metals and several organic toxicants may accumulate in water or sediments and pave their way to the operative food chains leading to biomagnification in diverse organisms at consequent trophic levels (Vander et al., 2003; Asagba et al., 2008). The literature survey indicated that extensive work has been carried out in rivers, estuaries and coastal wetlands as compared to that on ponds and lakes. Several experimental studies reported systemic and target specific toxicities of industrial pollutants proving potential health hazards

(Table 2).

1.1.1. Indian Environment

There are more than 4000 industrial units in India manufacturing a wide variety of products such as pulp and paper, sugar, hydrogenated oils, petrochemicals, antibiotics, dyes and chemicals, fertilizers, paints, rubber, jute and many other materials, whose discharges into the ecosystem lead to the deterioration of water bodies. The presence of oil in water is undesirable since spread of oil over the surface of water inhibits the diffusion of oxygen in it. It is reported to coat the gills of the fishes and thus affect respiration process (Sesha and Rao, 1999). Industrial pollution, besides being a hazard to the human population, is also responsible for the adverse effect on the aquatic life.

During past 5-6 decades, the ambient environment of India has drastically changed due to rapid and extensive industrialization (Fig. 4). With extensive agricultural practice the consumption of fertilizers and pesticides has also enormously increased (Table 4). The release of agricultural runoff and industrial discharges has degraded the qualitative standards of aquatic bodies which indicated that in several large rivers of India the BOD values have remained high in recent past (Table 5). The analysis of qualitative status of some estuaries in India suggested that the estuaries in Gujarat are highly polluted and degraded in terms of various environment attributes (Table 6). Studies have reported that pollution inputs in rivers and wetlands lead to extensive eutrophication and high BOD value because of organic chemical discharges leading to oxygen depletion. A brief review of Indian literature is presented in Table 7 describing the impact of pollution in rivers of India. Although the standards for permissible levels of pollutants for release in an aquatic body are prescribed, however, the quality of actual discharges never matches with it (Table 8). Central Pollution Control Board (CPCB) has defined criteria for release of pollutants from specific industries in view of the diversity of the discharges.

Extensive literature is available on experimental evaluation of toxicity in different target and non target animals. However, the correlations of in situ and experimental conditions are only a few. Generally, the experimental doses are never represented in natural conditions and therefore, the dose responses claimed in experimental evaluations may not be those encountered in natural exposure conditions (Baxi et al., 2009, Vachhrajani, 2009). In present studies, therefore, comparison of toxicity is made between fishes exposed to toxicant in situ and under experimental conditions.

Abiotic and biotic status studies of freshwater bodies have been major component of research on limnology (Dhuru, 2002; Prasad and Singh, 2003; Pinto-Coelho et al., 2005; Nair, 2007; Nayaka et al., 2009). Although, the size, usage and variability of inputs differentially influence the quality of aquatic body, researchers have mostly investigated routine physicochemical properties of the aquatic system (Jindal, 1993; Ara et al., 2003; Awasthi and Tiwari, 2004; Kumar and Kapoor, 2006). During past 4-5 decades, pollution inputs from domestic and industrial wastes have been the major components of research. The pollutant induced changes in the physicochemical properties of water have extensively been investigated (Desai et al., 1981; Cottenie et al., 2001; Begum et al., 2003; Nanda and Vachhrajani, 2002; Sharma, 2006;

Rejomon et al., 2008). It may be of interest to note that since volume wise large pollution discharges are usually in the streams and rivers, these systems have dominated as the research sites (Nanda et al., 2005). With increasing interest in village ponds as fish culture sites, the investigations on impacts of pollution were diverted towards pond system during past 2 decades. Studies both on freshwater and marine systems have reported toxic potentials of various pollutants on planktonic and benthic fauna as well as demonstrated that zooplankton accumulate metals several thousand times more than those detected in water (George and Kureishy, 1979; Khan and Rao, 1981; Gajbhiye et al., 1985; Gautam, 1990; Zauke et al., 1996; Pandya et al., 2007).

Experimental studies in fishes to assess the toxicity of individual chemicals are innumerable both in international and Indian literature. In several cases researchers have exposed the fishes to a group of toxicants to mimic the natural exposure conditions. The toxicant exposure in natural or experimental conditions is reported to alter the reproduction and development, general physiology and even behavior of the fishes (James and Sanpath, 1999; Witeska and Jezierska, 2003; Scott and Sloman, 2004; Viana et al., 2005; Sloman, 2007). The toxicant induced generation of oxidative stress and consequent alterations in metabolism have been studied the most in various tissues of fishes the world over (Oladimeji, 1987; Pandey et al., 2003; Lefebvre et al., 2004; Farombi et al., 2007; Mohamed et al., 2008; Slatiinska et al., 2008; Jeane et al., 2009). The biomagnifications of pollutants, especially heavy metals, is one of the major concerns for research on aquatic systems (Akoto et al., 2008; Ogwok et al., 2009). The food chain contamination ultimately leads to accumulation of metals in the tissues of fishes (Vander et al., 2003; Asagba et al., 2008). This may pave its way to humans (Sharma, 1995).

1.1.2. Gujarat Environment

Gujarat is one of the most industrialized states of India. It has 3 large petroleum refineries, 5 petrochemical complexes, 6 major chemical fertilizer complexes, 9 chloralkali plants, 5 soda ash plants, 12 major chemical industrial estates and 5 major chemical industrial complexes at Atul, Hazira, Vadodara, Jamnagar and Mithapur. To overcome the problem of environmental pollution it has 19 Central Effluent Treatment Plants, 6 hazardous solid waste disposal sites, 4 incenerators of hazardous solid wastes and 6 treated effluent conveyance pipe lines which release the effluent into the lower estuarine or the near coastal regions. The large industrial units are those of petrochemical and downstream products, dyes and intermediates, pesticides and intermediates, pharmaceuticals and intermediates, salt, alkalies and marine based chemicals, organic and inorganic chemicals, agro based chemicals and paints etc. Gujarat's contribution to production in India has been prolific with soda ash being 100%, salt 85%, polymers 56%, ethylene and acetic acid 50%, caustic soda 41%, phosphatic fertilizers 38% and nitogeneous fertilizers 20% etc.

The chemical industries development region along the west coast from Vapi to Ahmedabad is referred as Golden Corridor of Gujarat. Most of the severely water polluting sites are located in this region; being 68 in Valsad, 89 in Surat, 74 in Bharuch, 53 in Vadodara and 154 in Ahmedabad. A CPCB survey (2007) carried out in these industrial areas had identified 1349 units generating and disposing heavy metals, toxic organic compounds, oils and emulsions, spent chemicals and incineration ash. The Vadodara industrial complex has 3 Gujarat Industrial Development Corporation (GIDC) zones supporting hundreds of industrial units. The chemical industrial units are located in Nandesari GIDC spread over several villages like Angarh, Bajwa, Dhanora, Karachia, Nandesari, Ranoli, Koyali etc (Fig. 5). The hazardous chemicals used/produced by the industries of this area are listed in Table 9. The industrial effluent contained several organicals and metal based compounds (Labunska et al., 1999; Yossafzai, 2004). These are listed in Table 10. Several of these chemicals have been shown to induce abnormal mitosis, inhibit the growth of cultured plant cells and adversely affect overall growth of the plant. These chemicals have been found in food, breast milk and drinking water.

Ankleshwar industrial area is one of the largest chemical industrial areas in Asia. Due to release of pollutants directly into the surrounding environment the aquatic bodies are highly polluted in this region (Table 11). Heavy metal contamination zones in the shallow aquifers and variations in the qualitative status of the groundwater was studied for Ankleshwar industrial area which indicated high pollution levels and occurrence of different metallic compounds simultaneously enhancing the toxic potentials (Kumar and Pawar, 2008; Kumar et al., 2008). Similarly, extensive pollution in the industrial area around Vadodara is reported where surface as well as ground water are polluted and contain high levels of toxic metals (Tables12 and 13). The 56 km long channel carrying the effluent from industries around

Vadodara passes through Vadodara and Bharuch districts and the effluent is released into Mahi estuarine region (Figs. 6 and 7). The chemical analysis of effluent carried out in earlier studies from our laboratory over a period of about 15 years is presented in Table 14. The values are average of 2 to 4 samplings carried out during a year. The findings suggested that the toxicant levels greatly vary over the period but these are generally much beyond the permissible levels. The variations in toxic chemical levels may be due to the variations in contents and amount of effluent released by different industries during different time periods. Unfortunately, the effluent from the channel is directly used for irrigating the agricultural field in its vicinity. Earlier studies from our department clearly showed accumulation of toxic metals into variety of farm produce of such irrigated fields (Table 15). Several industries around Vadodara release air pollutants also (Fig. 8). The status of ambient air quality of Vadodara industrial and residential (city) area indicated high level of air pollution (Table 16). The proposed Delhi Mumbai Industrial Corridor will pass through the existing Golden Corridor of chemical industrial zone of Gujarat and has extensive development plans from infrastructure to industrial establishment (Fig. 9).

On the other hand, the aquatic bodies have been considered for conservation under various programmes like National Wetland Conservation and Management Programme (NWCMP) as well as the Ramsar Convention. In Asia 206 wetlands have been identified as Ramsar sites (Figs. 10 and 11). Gujarat has extensive wetland area, although distributed largely in Kachchh district (about 80% of total). Vadodara district has about 5,560 ha of wetlands which have individual area of less than 300 ha and a total of 11,261 ha where individual wetland has an area of about more than 300 ha (Table 17). Several of these wetlands are regularly monitored for the quantitative status. The analysis of certain important ponds distributed in different regions of Gujarat suggests important findings (Table 17). It is interesting to note that some of these are urban ponds and some are declared protected areas (Table 18). In India, 94 wetlands are identified under National Wetland Conservation and Management Programme (Table 19). Of these, 8 sites are located in Gujarat (Nal Sarovar Bird Sanctuary, Greater Rann of Kachchh, Thol Bird Sanctuary, Khijadiya Bird Sanctuary, Little Rann of Kachchh, Pariej, Wadhwana and Nani Kakrad) (MOEF, 2007). Twenty five sites in India are considered important internationally under Ramsar Convention. Under National Lake Conservation Programme 42 lakes in India are identified for conservation management (MOEF, 2007).

1.2. Lentic Ecosystems

Although, vicinity of towns and cities are also urbanized, the ponds are still a traditional component of villages. Several of the ponds have drastically shrunk but others are utilized for various domestic activities. The village ponds in some part of Gujarat are also used for fish culture. Since the ponds are used for domestic purposes and for domestic waste discharge directly into it, these have become highly polluted, at times eutrophicated or infested with weeds and over the decades these have degraded as natural resources. In some of such ponds around Vadodara water quality studies have been carried out earlier (during 1995-2005) which indicated conspicuous reduction in dissolved oxygen, high levels of phosphates, increase in hardness and alkalinity and alteration in pH. The lentic system is comparatively close system with least possibility of toxicant dispersal and dilution. The water residence time in a lentic ecosystem on an average is 10 years and that of lotic ecosystem is 2 weeks. In lotic ecosystem, the average flow velocity ranges from 0.1 to 1 m/s whereas lentic ecosystems are characterized by an average flow velocity of 0.001 to 0.01 m/s (Wetzel, 2001).

In most aquatic food chains, the community interactions are often controlled by abiotic factors or predation at higher levels of food chain. The control of primary production by biotic factors such as nutrients is called "bottom-up control". The control of primary production by the upper levels of food chain is referred to as "top-down control". The idea that predation at upper levels of food chain can have cascading effect down through the food chain is called the "trophic cascade" (Dodds, 2002). The bottom-up hypothesis requires that the biomass of all trophic levels is positively correlated and depend on limiting resources of the system. The top-down hypothesis predicts, however, that the adjacent tropic levels will be negatively correlated. Finally, a combined regulating theory, bottom-up: top-down, combines the predicted influences of consumers and resource availability. It predicts that trophic levels close to the lowest trophic strata will be most influenced by bottom-up forces, while top-down effects should be strongest at top levels.

1.3. Biological Impact Assessment

The judicious exploitation, careful utilization and maintenance as well as management of the natural resources are basic components of Biological Impact Assessment (BIA). While considering the approaches for an overall environment quality management, following aspects are taken into account:

i. Environmental perception and public awareness.

ii. Environmental education and training.

iii. Resource management.

iv. Control of environment degradation and pollution.

v. Appraisal of existing environmental condition.

vi. Appraisal of existing and proposed production methods and technologies.

vii. Probable impact of existing and proposed project on the environment.

viii. Development of conservational, ecological and regulatory techniques.

The understanding of BIA process has greatly increased during the last two decades. The biological monitoring is commonly based on the presence or absence of taxa as indicators of aquatic system status. However, the community structure, trophic organization and operative food chains analyzed over a period of time may actually give understanding of the biological impacts. When the status of an ecosystem is not much elastic, mild disturbances might not produce any appreciable alteration in habitat specifications and community structure. Research reports highlight the impact of pollution and other factors on the limnology, however, many are lacking in a long term sequel of pollution impacts on both the abiotic and biotic components. Therefore, it is necessary to combine both biological and chemical monitoring for comprehensive analysis of the status of the aquatic system (Andrade et al., 2004; Cowx and de Jong, 2004; Gadzala-Kopciuch et al., 2004; Govindsamy et al., 2008). Aquatic animals have often been used in bioassays to monitor water quality. Planktons have been used as indicators of ecosystem changes. The development of biological monitoring techniques based on fish offers the possibility of checking water pollution with fast responses on low concentrations of direct acting toxicants (Ali and El-Shehawi, 2006). Since fish often respond to toxicants in a similar way to higher vertebrates, they can be used to screen the chemicals that are potentially teratogenic and carcinogenic in humans. The main application of model system using fish is to determine the distribution and effect of chemical contaminants in the aquatic environment.

Ecotoxicological research took momentum during seventies; however, comprehensive studies were carried out extensively during past two decades. An editorial by Cairns (1989) entitled "**will the real ecotoxicologist please stand up**?" focuses the image and dilemma of ecotoxicological research. The pollution impact studies have been based mainly on the chemical analysis of the system considering the pollution sources. The biological component, although included, is not given sufficient importance. However, the environmental impacts on an ecosystem can be understood better if biotic impact assessment is considered since the long term effects can be estimated in terms of impact on biota, changes in food chain and webs, variations in community composition, reproduction success rate and larval settlements etc. Several studies have reported toxicant accumulation in the tissues of animals through food chains of polluted ecosystems. The biological monitoring is commonly based on the presence or absence of taxa as indicators of aquatic system status. However, the community structure, trophic organization and operative food chains analyzed over a period of time may actually give understanding of the biological impacts. Simultaneously, the chemical status of aquatic body, particularly with reference to pollutant inputs and concentrations, also carried out over a period of time, may correlate the biological and chemical status of the aquatic system. Research reports highlight the impact of pollution and other factors on the limnology, however, many are lacking in a long term sequel of pollution impacts on the biotic components (Irigoien, et al., 2009). Therefore, it is necessary to combine both biological and chemical monitoring for comprehensive analysis of the status of the aquatic system (Sladecek, 1983; Andrade et al., 2004; Gadzala-Kopciuch et al., 2004; Govindsamy et al., 2008).

1.4. Initiation of the Research Idea

The environment is currently polluted by thousands of chemicals or xenobiotics introduced into the environment by man to meet the demands of the modern era. Every day we encounter this negative side of human civilization, but have done little to lessen the rate of pollution. The purpose of this study was to collect sufficient base line water quality data to define current limnological condition and to provide a basic for future water quality protection and monitoring (Mishra et al., 2008).

Fresh water recourses have deteriorated both in quality and quantity in many areas of the world. Ponds, fresh water recourses that have been most influenced, receiving agro industrial discharges, chemical contamination etc. consequently cause damage to ecosystem and health of stake holders.

Fishes are highly sensitive even to small environmental changes and their population gradually dwindle if pollution continues unabated. Thus, fishes are considered reliable bioindicators of water pollution and fish ecotoxicology has received much attention in recent years. In past decades, numerous studies on the effect of oxidative stress caused by some environmental pollutants in terrestrial and aquatic species were published and earlier studies form this department has focused on impacts of industrial pollutant using estuarine zooplankton and laboratory rats as model.

So, this study investigates the:

- Overall qualitative status of lentic water bodies.
- Pollution impacts on zooplankton.
- Pollution impacts on fish.

1.5. Lacuna of Knowledge

Although, literature on monitoring of aquatic pollution may appear huge, a large gap of understanding still exists since many studies have not correlated the natural and experimental conditions of exposure and toxic manifestations. When the pond aquaculture practice is gaining large scale acceptance as a potential employment generator industry and cause of socio-economic uplifting in several parts of India and in particular Gujarat, it seems more feasible to understand the pollution status of such aquatic systems.

1.6. Objectives

I. Analyze general qualitative status of aquatic ecosystem.

Assessment of physicochemical parameters of water suggests overall abiotic quality status of the pond. A comparison of seasonal variations in abiotic status was made to correlate with biotic status.

II. Analyze pollution status of aquatic ecosystem.

As the study sites are in close vicinity of chemical industries that pose threat of solid, liquid and gaseous pollution, analysis of water can give status of pollution and type of pollutants present.

III. Study planktonic community.

Zooplankton community structure is an indicator of biotic status of the ecosystem. A variation in community diversity and species density was correlated with toxicant inputs.

IV. In situ and experimental studies to assess responses of fish to toxicant exposure.

The selected fish species exposed to toxicants in natural habitat collected and liver, muscle and gills processed for certain biochemical and histological analysis. Accumulation of toxicants in these tissues was also estimated. The same species collected from a non polluted pond was experimentally exposed to toxicants at different dose levels to study toxic responses.

V. Biological impact assessment studies.

The study sites were surveyed for certain invertebrate and vertebrate fauna. The industrial and non industrial sites were compared for their faunal diversity.

These objectives comprehensively analyzed the industrial pollution posed threat to aquatic biota. Further, the comparison of terrestrial biota of industrial and non industrial zones will help define overall pollution and their impacts.

1.6.1. Rationale for objectives

The main reason for assessment of quality of aquatic environment has been to verify whether the observed water quality is suitable for intended use. The overall process of evaluation of physical, chemical and biological nature of water in relation to natural quality, human effects and intended uses, particularly the uses which may affect human health and health of the aquatic ecosystem itself is termed as water quality assessment (UNEP, 1996). Thus the water quality assessment program aims,

- To provide water quality details to decision makers and public on the quality of freshwater relative to human and aquatic ecosystem health and specifically,
- To define the status of water quality.
- To identify and quantify trends in water quality.
- To define the causes of observed conditions and trends.
- To identify the types of water quality problems that occurs in specific geographic areas.

- To provide the accumulated information and assessment in a form that resource management and regulatory agencies can use to evaluate alternatives and make necessary decisions.

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Biological impact assessment involves the use of biotic components of an ecosystem to assess periodic changes in the environmental quality of the ecosystem. A variety of effects can be produced on aquatic organisms by the presence of harmful substances, the changes in the aquatic environment that result from them, or by the physical alteration of the habitat. As all of these effects are produced by a change in the quality of aquatic environment, they can be incorporated into biological methods of monitoring and assessment to provide information on a diverse range of water quality issues and problems,

Biological impact assessment of water and water bodies is based on five main approaches (UNEP, 1996):

i. Ecological methods:

- Analysis of biological communities of the water body;
- Presence or absence of specific species.

ii. Physiological methods:

- Studies of the effects on enzymes.

iii. The use of organisms in controlled environments:

- Assessment of toxic effects of samples on organisms under defined laboratory conditions (toxicity tests or bioassays), and
- Assessing the effects on defined organisms of waters in situ or on site, under controlled situations and in vitro condition.

iv. Biological accumulation:

- Studies of the bioaccumulation of substances by organisms living in the environment,
- Studies of the bioaccumulation of substances by organisms deliberately exposed in the environment.

v. Histological and morphological methods:

- Observation of histological and morphological changes.

In present studies all these standard criteria were considered for a comprehensive biological impact assessment of the industrial pollution on the lentic system.

Table 1: Impact of aquatic pollutants on flora and fauna (International status)

River/Estuary/Lake	**Specific effect**	**Author**
Streams in north-eastern USA	Very low pH leading to acidification and long term decrease in the fish communities.	Baker et al., (1996)
Lakes in Sudbury Ontario, Canada	Very low pH and high conc. of metals like Ni, Cu and Al leading to elevated biomass of planktonic Rotifers species Keratella and Triocera.	Yan and Zeiling, (1985)
King river, Tasmania, Australia	Elevated level of Cu and Zn leading to fluctuation in the population of zooplankton.	Swain and White, (1985)
Kummato zoo basin, Japan	High temp low dissolved O2 and high N2 content leading to fluctuation in the population of zooplankton.	Bunyat et al., (1998)
Rivers of east of France	High conc. of ammonia, phosphate and chlorine leading to decrease in no of Oligochaeta.	Lafont, (1984)
Lakes of eastern Poland	High conc. of nutrients high nanoplankton biomass and increased fertility in *Branchionus angularis*.	Radhwan, (1980)
Chesapeake bay and Elizabeth river, USA	Increase in eutrophication and decrease in Tintinids, copepod naupli and mesozooplankton.	Park and Marshal, (2000)
River Medlock and tributis Manchester England,	Decrease in Protozoans, copepod and mesozooplankton population.	Chiu and Frost, (1988)
Delaware and Neeches estuaries and flint river	Increase in density of pollution tolerant oligocheates and polycheates.	Patrick and Palvage, (1994)

Table 2: Review of systematic toxicology of common industrial chemicals

Compounds	Observation	Authors
Chromium	Effects enzyme activities which disturb normal testicular physiology at adulthood in males. Delayed sexual maturation, reduced number of implantation and viable foetus in females	Saxena, (1990) Al Hamood, (1998)
Cadmium	Decreased gonad weight, significant maternal toxicity, necrosis in males	Pasky et al., (1997) Baransky et al., (1982) Foote, (1999)
Lead	Delayed sexual maturation Morphology of spermatozoas are effected	Badeger, (1998) Pinon, (1993)
Aluminium	Decrease in spermatid counts	Clobat, (1995)
1,3 butadiene	Direct toxic to developing embryo	Mehlman, (1991)
Polychlorinated biphenyls	Increase in testis weight	Batty, (1990)
Industrial effluent	Significant reduction in embryonic growth of mallard.	Hoffman and Easrin, (1981)
Diesel exhaust	Depression in releasing hormones	Watanabe, (1999)

Table 3: Fertilizer inputs in some of the Indian states (annual averages)

State	Nitrogen	Phosphate	Potassium
Punjab	125	42	2.5
Andhra Pradesh	73	34	9.6
Haryana	78	27	0.9
Tamil Nadu	71	29	41.8
Maharashtra	37	17	10.3
Gujarat	43	22	5.8

Alagh et al., 1995

Table 4: Pesticide consumption in some of the Indian states

States	Total tones	Per acre of cropped area(Kg)
Tamil Nadu	11,600	-
Andhra Pradesh	12,000	0.83
Punjab	4,800	0.87
West Bengal	5,000	0.56
Mahatrasta	4,000	0.23
Gujarat	5,000	0.63

Alagh et al., 1995

Table 5: Biological Oxygen Demand analysis of some important rivers if India

Rivers	2002	2003	2004	2005	2006
Mahi	3	3.4	4.9	5.9	8.5
Amlakhadi	1561	1463	947	714	582
Tapi	10	10	36	25	24
Narmada	3.5	33.3	3.8	4.5	3.7
Sabarmati	475	275	380	207	293
Ganga	17	27	16.8	15.2	10.4
Yamuna	36	58	40	59	144
Kali	67	149	165	136	160
Godavari	78	53	15	20	160
Krishna	10	17	9	40	16.8
Cauvari	26	10	9	12	6
Mahanadi	7.6	5.6	4	16	10
Bramputra	3.9	3.5	4.3	6.2	4.3
Satlaz	45	24	64	40	32
Beas	5	6	4.8	10	3.2

CPCB, 2007

Table 6: Environmental status of major estuaries in India

Attribute	Mahi	Narmada	Tapi	Hoogly	Godaveri	Caveri
Population congestion	2	2	2	3	2	2
Deforestation	1	1	1	3	2	2
Land productivity	3	3	3	1	1	1
Mine soil dumps	1	1	1	2	1	1
Water quality	2	1	3	1	1	1
Air quality	1	1	3	1	1	1
Soil erosion	3	3	3	3	2	2
Noise levels	1	1	1	1	1	1
Resource constrains:						
-Water	3	2	3	1	1	1
-Power	2	2	3	3	2	2
-land	1	1	3	2	1	1

The Hindu: Survey of Indian Environment, 2000.

Table 7: Impact of aquatic pollutants on flora and fauna (National status)

River	Specific effects	Author
River Ganga, Patana, Bihar	High BOD and nutrients leading to decrease in population of macro organisms and making water unfit for human consumption	Khare et al., 1979; Das and Sinha,1994
Tapi estuary, Surat, Gujarat	High temperature, salinity, pH, silicate and calcium and low, dissolve oxygen low nutrient concentration leading to high diatom population.	Ragothaman and Reddy,1982
River Kshipra ,MP	High BOD and COD leading to depletion of benthos	Augstine and Diwan,1991
River Khan, MP	Fluctuation in physicochemical parameters leading to unstable community structure of macrobenthos	Kulshrestha et al.,1994
River Godaveri, Tungbhadra and Moosi, Andhra Pradesh	High conc. of heavy metals viz. Iron, nickel and lead etc, elevated density of certain species of Euglena, Ocillatoria, nitzschia.	Vankteshwarlu et al., 1994
River Tungbhadra, Andhra Pradesh	Increse in bicarbonates, chlorine, phosphates, total solids and hardness leading to decrease in general species diversity.	Reddy and Vankteshwarlu, 1996
Mula, Mutha Pune, Maharastra	Increase in nutrients leading to a drastic drop in number and species richness of both phyto and zooplanktons especially Arthropods.	Yazandoost and Katdare, 2000
River Coovum and Adyar, Chennai, Tamil Nadu	Fluctuation in plankton population associated with fluctuation in physico chemical parameters	Varadani and Oza,1985

Table 8: Permissible level of pollutants for release in the aquatic system (BIS standards)

Parameters	**Maximum permissible concentration**
Temperature	45° C
pH	5.5 to 9.0
Total suspended solids(mg/l)	100
Total dissolved solids (mg/l)	500
Biological oxygen demand(5days,20° c)(mg/l)	100
Oil and grease(mg/l)	10
Phenolic compounds(mg/l)	1
Cyanide(mg/l)	0.2
Sulphide(mg/l)	1
Fluoride(mg/l)	10
Arsenic(mg/l)	0.2
Barium (mg/l)	1
Cadmium(mg/l)	2
Copper(mg/l)	3
Chromium(mg/l)	0.1
Nickel(mg/l)	3
Lead(mg/l)	0.1
Mercury(mg/l)	0.01
Zinc(mg/l)	10

Table 9: List of hazardous chemicals identified in waste water and solid waste from the industries of Nandesari area

Name of Industry	Hazardous Chemical(s) Used/ Products /By Products
Reliance Industries Limited	Caustic Soda, Ethylene, Propylene Butadiene, Toluene Xylenes, Ethylene, Glycol, DEG, Ethylene-Oxide
GACL	Caustic Sauda, Sodium Hydrochloride, Liquid Chlorine, Compressed Hydrogen Gas, Hcl, Caustic Potash, Aluminium Chloride, Poly Aluminium Chlorides
GSFC	Kaprolactum, Methyl Ethyl Ketoximemelamine, Anhydrous Ammonia, Nylon 6, Ammonium Sulphate, Sulphuric Acid
IOCL Gujarat Refinery	Petrol, Diesel, Naphtha, Kerosene, LPG, Linear Alkyl Benene, H_2S, Sulpher, Various catalysts, Hydro-carbon Odours, H_2S, So_x, oil, phenol, sulphide, benzopyrene, Cynide, Ammonia
Deepak Nitrite Ltd	Nitric Acid, NOx
Ester India	Dimethyl Hydantoin, Halogenated Hydantoins, Succinimide, Halogenated Succinimide Acetic- Acid, Acetic anhydride, Acetocynohydrine, NH4, Bromine, Cl2, HCL, Isopropanol, Methanol, Nitric Acid, Phos Oxi Chloride, Sodium Hydroxide, Thionyl Chloride, Toluene
Spa Vet Min Pvt Ltd	HCL, Residue of Rock Phosphate
Diamines and Chemicals	Ethylene Amine, NMP, ammonia , sodium hydroxide, CPA, MMA, GML
Nahar Pharma Chem	Mono Chloro-Acetic Acid, Iso Propyl Alchol, MethylAlcohol, H_2SO_4, Ammonium Hydro-Oxide, Cholo Acetetes, Etp Sludge,
Nandesari Rasayanee	Carbon Sludge
Chlori Tech Industries	Chloral HCl, Cl_2
Sodium Metal Pvt Ltd	Acetyl Trityl Chloride, DIPPN, PPAN,CDAM Acetyl Chloride, HCl, Soda amine, Isopropyl Bromide, Benzyl Chloride, Methanol, Aluminium Chloride
Ushma Industries	Borax Anhydrous, Boric Acid, Sodium Nitrate, Zinc Carbonate, Saccharin, Halazone Usp Etp Sludge, Hdpe Bags, Liner
Reckon Petrochem	Mono Chloro Acetic Acid, HCL, Ascorbic Acid, Acetic Acid
Farmson analgesics	PCM, Acetic Acid
Panoli intermediates	PNC/ONC, Benzene
SUD chemicals	Catalysts
Sodium metals	Triphenyl Chloride
New field industries Equipments	Machinary and Parts, Sluge
Panoli intermediates	VS, HCl, Sodium Sulphate
Chloritech industries	Liquid Chloral, HCl
Gujarat dyestuff	Vinyl Sulphone Esters, HCl
NTP tar products	Blown Grade Bitumen
Gandhar petrochem	Vinyl-Sulphone Ester, Acetic Acid
Nikunj Chemical	Chlorinated Paraffin, Dicalcium Phosphate, Hydrochloric Acid, Acetic Acid Glacial, Sodium Sulphate, Meat tenderiser, Zinc Oxide, Methyl 12 Hydroxy Stearate, Sulphuric Acid, Sodium Metabisulphite

Table 10: Chemicals and derivatives found in the effluent discharges from the industries around Vadodara

Industrial waste water	**Industrial Solid waste**
1,1-Biphenyl and derivatives	1,1-Biphenyl and derivatives
1,3 Butadiene and derivatives	1-Tetradecene
6-Tridecene	Aliphatic hydrocarbons
9 H-Carbazole	Alkylbenzenes
Acridine derivative	Azulene
Aliphatic hydrocarbons	Benzenamine and derivatives
Alkylbenzenes	Benzene and derivatives
Alkylphenol derivatives	Ocytyl phenol
Benzenamine and derivatives	Benzene methanol
Benzene and derivatives	Biphenyl derivatives
Benzenemethanamine	Chlorinated methoxy benzene
Benzenemethanol	Diazene
Benzenethiol	Dibenzothiophene and derivatives
Benzofuran	Docosane
Benzonitrile	Eicosane
Chlorinated benzenamine	Heneicosane
Cyclododecane	Heptadecane and derivatives
Cyclohexadecane	Hexacosane
Decane	Hexadecane and derivatives
DEHP	Naphthalene derivative
Diazene and derivatives	Nonadecane and derivatives
Disulfide	Octadecane and derivatives
Docosane	Octadecanoic acid,
Eicosane	Organosulphur compounds
Eicosane	PCB-135, 136
Ethanone	Pentacosane
Heneicosane	Pentadecane and derivatives
Junipene	Phenanthrene derivative
Naphthalene derivative	Tetracosane
Nonadecane	Tricosane and derivatives
Octadecane	Tridecane
Organonitrogen compounds	
Organosulphur compounds	
PCB-3,9,10,13,19,24	
Pentadecane	
Phenazine	
Pthalates	
Pyridine	
Thiophene	
Tricosane	
Tridecane	
Valencene	

Labunska et al., 1999

Table 11: Water quality status of Amla khadi, Ankleshwar

Location	Parameters					
	pH	TSS	TDS	COD	BOD	NH_3-N
At Valia Chowkdi(Day Time)	7.2	355	3706	1447	473	266
At NH Crossing(Day Time)	7.5	48	1120	162	52	11.2
Near FETP,Ankleshwar(Day Time)	7.4	78	3122	496	144	140
At Valia Chowkdi(Night Time)	7.9	150	3120	1269	437	316
At NH-8 Crossing(Night Time)	7.5	10	1064	206	33	375
Near FETP,Ankleshwar(Night Time)	7.1	207	5524	1854	550	333
At Valia Chowkdi(Day Time)	7.1	142	3132	865	306	106
At NH Crossing(Day Time)	7.8	22	496	37	10	6.0
Near FETP, Ankleshwar(Day Time)	7.7	62	2286	537	194	112
At Valia Chowkdi(Night Time)	7.92	308	4936	1568	407	246
At NH-8 Crossing(Night Time)	7.4	320	2526	600	98	146
Near FETP, Ankleshwar(Night Time)	7.1	92	2708	464	63	81

CPCB, 2007

Table 12: Heavy metal analysis in water samples of industrial area around Vadodara

Heavy metals	Content (µg/l)
Cd	<10
Cr	60
Co	20
Cu	40
Pb	<30
Mn	90
Hg	<2
Ni	40
Zn	200

Labunska et al., 1999

Table 13: Ground water status in the industrial area around Vadodara

	Units	**Ranoli Gram Panchayat ground water**	**Dhanora Gram Panchayat ground water**	**Angarh Gram Panchayat ground water**	**Nandesari Gram Panchayat ground water**	**Koyali Gram Panchayat ground water**
Color		Colorless	Colorless	Colorless	Colorless	Colorless
Turbidity	NTU	1	1	2	6	2
TDS	mg/l	1099	1180	1215	1482	1093
pH	mg/l	7.6	7.7	8	7.3	7.6
Total hardness	mg/l	412	396	346	510	296
Calcium	mg/l	32	25	42	42	20
Magnesium	mg/l	48	34	58	69	12
Chlorides	mg/l	310	345	428	764	326
Alkalinity	mg/l	327	324	410	310	414
Sulphate	mg/l	33	32	32	98	28
Nitrate	mg/l	1.8	0.9	2.3	2.6	1.3
DO	mg/l	4.8	4.5	4.1	41	4.3
BOD	mg/l	18	14	8	22	12
Iron	mg/l	0.11	0.10	0.15	0.51	0.41

From the earlier work carried out at the Investigator's lab.

Table 14: Chemical analysis of industrial effluent collected from the effluent channel release site

	1996	1997	1998	1999	2000	2003	2005	2006
pH	7.2	6.8	7.4	7.2	6.7	7.0	6.9	7.8
Temperature	30.5	30	29.5	30	30	29.5	31	28.8
COD	350	227	208	215	320	376	395	428
BOD	186	103	356	128	204	228	243	250
TDS	1025	850	735	740	874	760	1102	1085
Oil And Grease	18	12	2	10	14	35	27	48.0
Phenols	1.2	0.59	ND	0.85	0.82	0.67	1.06	3.14
Ammonical Nitrogen	5.55	6.40	5.50	3.5	4.2	6.8	6.3	5.6
Total Kjeldahl N_2	7.3	9.5	5.8	5.5	8.3	4.6	6.3	7.4
Copper	1.65	0.40	0.11	0.30	0.62	0.37	0.42	0.75
Mercury	0.83	0.72	ND	0.4	0.06	0.21	0.03	BDL
Lead	1.50	2.1	0.06	0.30	0.61	0.86	1.22	0.18
Cobalt	2.85	2.93	1.16	0.62	0.23	0.51	0.09	0.08
Cadmium	0.65	0.75	0.50	0.33	0.31	0.17	0.21	0.15
Arsenic	0.03	0.02	ND	ND	ND	ND	ND	ND
Nickel	1.50	1.8	0.75	0.65	1.22	1.05	0.74	0.34
Chromium	2.45	1.29	2.62	1.86	0.63	1.16	0.65	0..2 8
Iron	3.80	1.7	1.35	0.66	2.59	2.32	1.08	0.52
Zinc	2.20	1.15	0.68	0.55	1.85	1.46	0.93	1.31

From the earlier work carried out at the Investigator's lab.

Table 15: Accumulation profile of several toxicants in various eatables and other items grown in the farms irrigated with industrial effluent directly from effluent channel

Metal (mg/kg)	Wheat	Bajra	Drumstick	Brinjal	Potato	Tomato	Grass	Tobacco
Copper	89.8	204	39	29	92	11.8	3.4	11.8
Chromium	3.4	63.2	3.1	2	1.6	7.6	2.1	9.9
Zinc	367.4	427.4	86.8	48.1	22.6	10.8	108.4	32.8
Nickel	2.1	3.2	2.2	18.8	2.3	2.3	3.9	2.5
Lead	2.4	2.9	9.2	26.3	9.8	91.3	40.8	44.5
Cadmium	21.3	10.7	7.9	8.8	8.8	6.2	3.0	65.4
Iron	41.3	25.7	12	32.1	10.1	31.2	21.2	20.7

Sharma, 1995

Table 16: Status of ambient air quality monitoring (Annual average April 2008 to March 2009)

City	Location of Monitoring Station	Parameters					
		RSPM	SPM	SO_2	NO_X	HC	CO
Vadodara	Nandesari CETP	116.63	268.86	19.02	45.07	1.84	1793.73
Vadodara	RO,GPCB Office	44.73	99.81	9.21	14.14	1.11	1098.53
Vadodara	Dandia Bazar	60.53	137.87	13.24	29.32	1.44	1403.59

CPCB, 2007

*All the values are in $\mu g/m^3$=micro grams per normal cubic meter and average HC is in PPM (Part per Million by Volume)

Table 17: Distribution of wetland categories in Gujarat state (area in Ha)

Districts	Wetland Category - Area		Total area	% of area
	Up to 300	Above 300		
Amreli	3409.01	15557.86	18996.87	0.63
Ahmedabad	12654.65	15052.57	27706.57	0.92
Banaskantha	15402.97	--	15402.97	0.51
Bharuch	7104.04	60859	67963.04	2.33
Bhavnagar	4889.98	64512	69401.98	2.30
Gandhinagar	354.83	--	354.83	0.01
Jamnagar	9370	97830.33	107200.33	3.55
Junagadh	5360.99	20572	25932.99	0.68
Kheda	19244.78	44117.50	46041	1.46
Kachchh	26775.16	2381012.11	2407778.27	79.62
Mehsana	3700.76	--	3700.76	0.12
Panchmahals	32829.18	--	32829.18	1.09
Rajkot	8471.17	18643.15	27114.32	0.90
Sabarkantha	20431.76	--	20431.76	0.68
Surat	5460.9	71653.02	77113.92	2.55
Surendranagar	120.76	14944.4	15065.16	0.93
The Dangs	1238.5	--	1238.5	0.04
Valsad	4625.09	30089.22	34714.31	0.56
Vadodara	5567.08	11261.00	16828.08	1.00

SACON wetlands report, Gujarat, 2007

District Porbander is included with Junagadh.

Table 18: Status of water quality of lakes /ponds of Gujarat

	pH	TDS	DO	BOD	COD	Ammonical N2	Total N2	Phosphate
Thol tank, Kadi	7.3	582	9.6	14.6	102	1.49	3.54	0.078
Nal Sarover, Sanand	8.1	2271	8.9	4.5	40	0.84	2.14	0.033
Monsar lake, Viramgam	8.9	3148	9.4	23.3	216	1.01	6.53	1.702
Bindu sarover, Sidhapur	7.5	685	7.1	25.0	109	0.42	4.62	0.593
Kankaria lake, Ahemdabad	8.2	763	5.6	6.6	51	1.40	4.01	0.230
Chandola Lake, Ahmedabad	8.5	564	8.0	5.0	165	0.84	8.40	0.262
Malav pond, Dholka	8.5	984	11.0	27.0	157	1.40	4.57	0.133
Sayaji Sarovar, Vadodara	8.2	155	8.3	5.4	19	1.12	1.75	0,084
Sur sagar Lake, Vadodara	8.0	1680	8.0	9.9	77	-	2.73	0.160
Gomati Lake	8.2	176	4.8	6.0	22	4.76	2.87	0.03
Dabhoi Lake, Dabhoi	9.6	932	7.9	15.0	146	3.92	4.20	0.12
Rana Pratap sarover, Halol	8.1	423	11.2	9.1	68	1.96	1.82	0.18
Ramsagar pond, Godhara	8.2	390	6.7	7.7	101	3.36	5.39	0.22
Lalpari lake ,Rajkot	7.6	290	10.7	3.2	70	4.48	6.62	0.65
Lakota pond Jamnagar	7.5	572	15.5	-	10	0.84	2.20	0.67
Narayan Sarover, Kachchh	8.7	786	7.0	6.2	30	0.56	-	0.48
Bore pond, Bhavnagar	7.9	206	8.1	2.0	10	1.05	2.24	0.65

Alagh et al., 1995

All parameters in mg/l except pH

Table 19: State wise distribution of wetlands under National Wetland Conservation and Management Program

States	Wetlands	Area (ha)
Andhra Pradesh	1	90100
Assam	2	4504
Bihar	3	11490
Chandigarh	1	148
Gujarat	8	1270875
Himachal Pradesh	5	15736
Haryana	2	288
Jammu and Kashmir	7	117325
Jharkhand	2	98965
Karnataka	7	4250
Kerala	5	213229
Madhya Pradesh	12	359814
Maharashtra	3	40298
Manipur	1	26600
Mizoram	2	285
Orissa	4	122580
Punjab	3	5648
Rajasthan	1	24000
Sikkim	6	164
Tamil Nadu	3	46283
Tripura	1	240
Uttar Pradesh	9	12083
Uttaranchal	1	800
West Bengal	5	553090

MOEF (Ministry of Environment and Forests), 2007

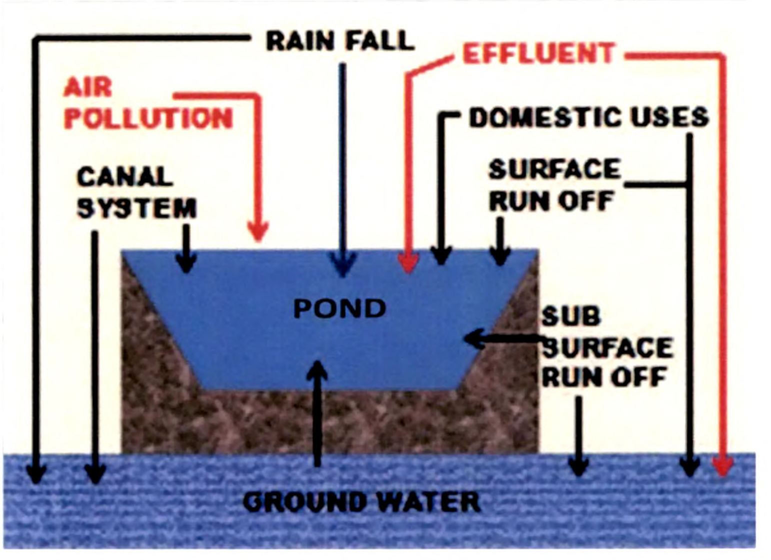


Fig1: Diagram describing the sources of pollution inputs to a water body.

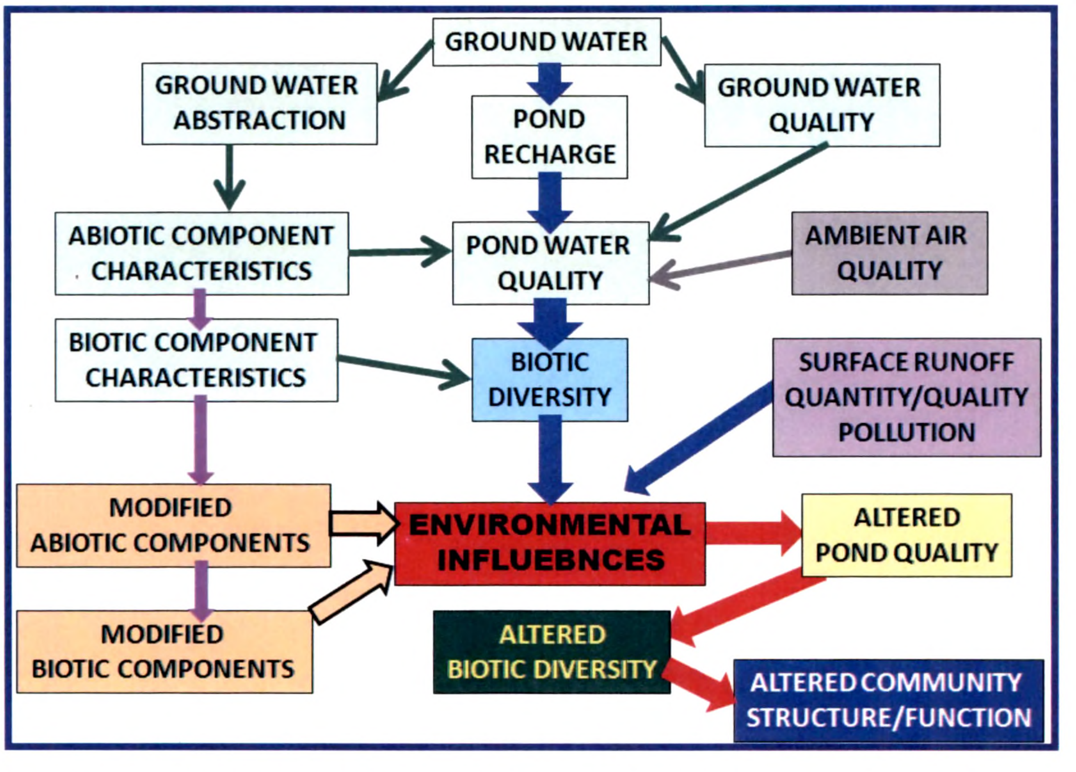


Fig. 2: The integrated network of various sources of pollution and their wide spread influences presented in an impact sequence diagram.

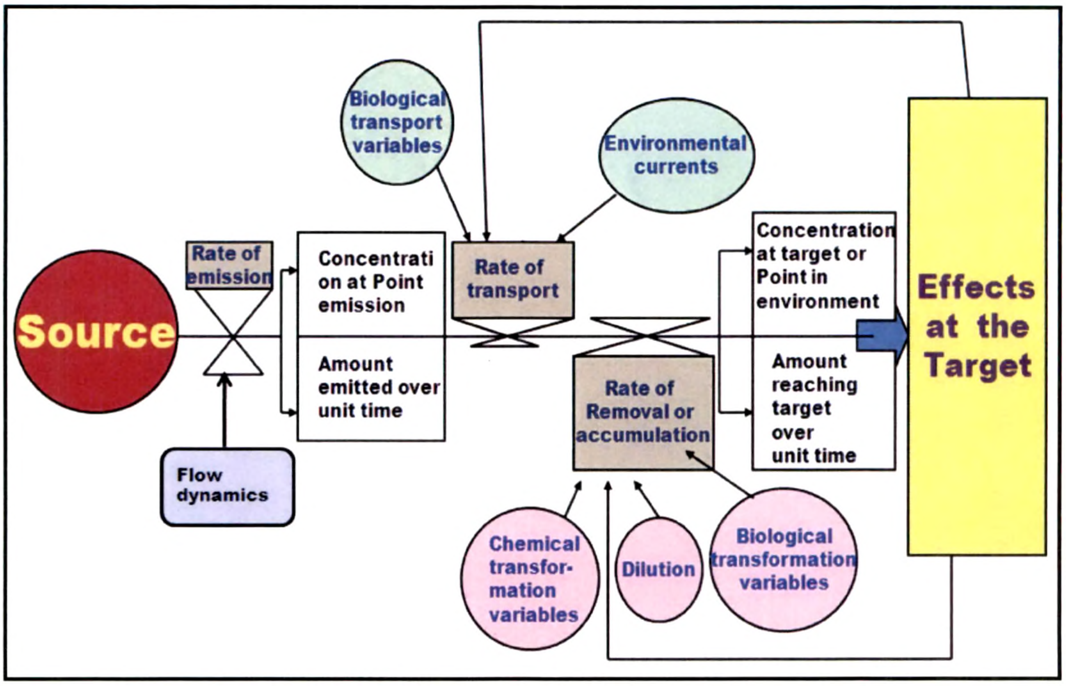


Fig. 3: Diagram describing the factors influencing the pollutant dispersal in an aquatic system.

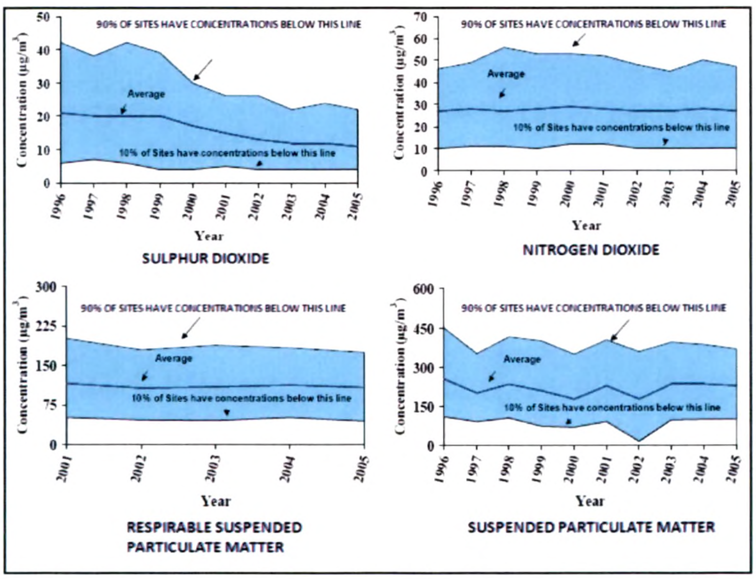


Fig. 4: Levels of major air polutants (avarage values for India) for ten year period. (CPCB, 2007)

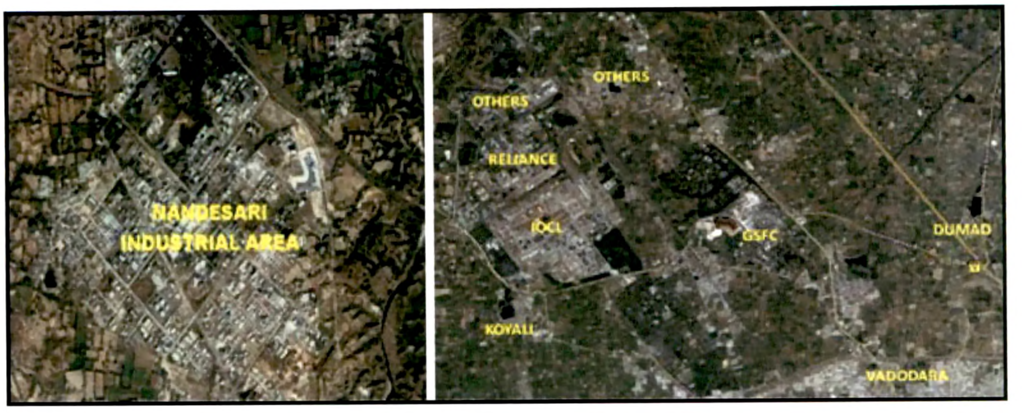


Fig. 5: Showing the Nandesari Industrial area and other industrial units in the study area. (Source: Google Earth)

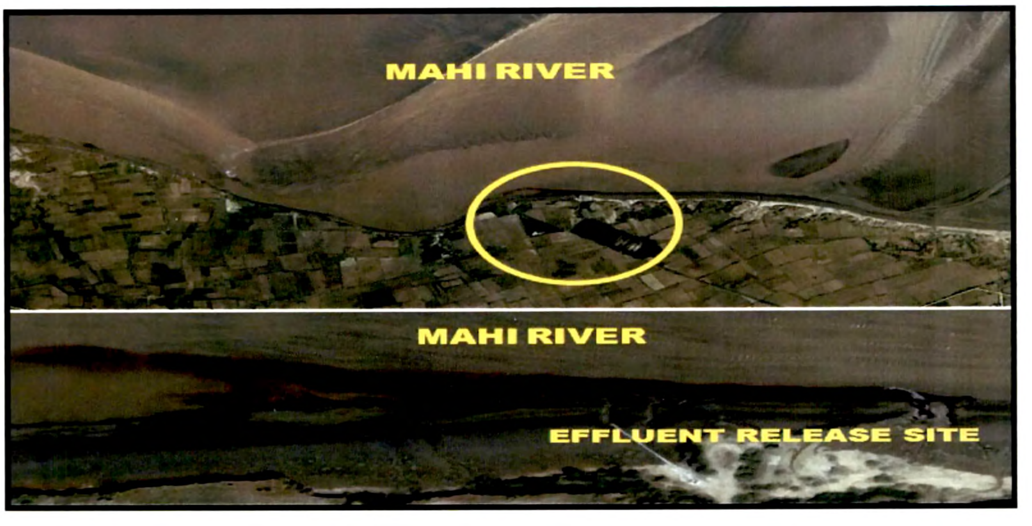


Fig. 6: Showing the industrial effluent releasing site in the lower estuarine area of Mahi River. (Source: Google Earth)

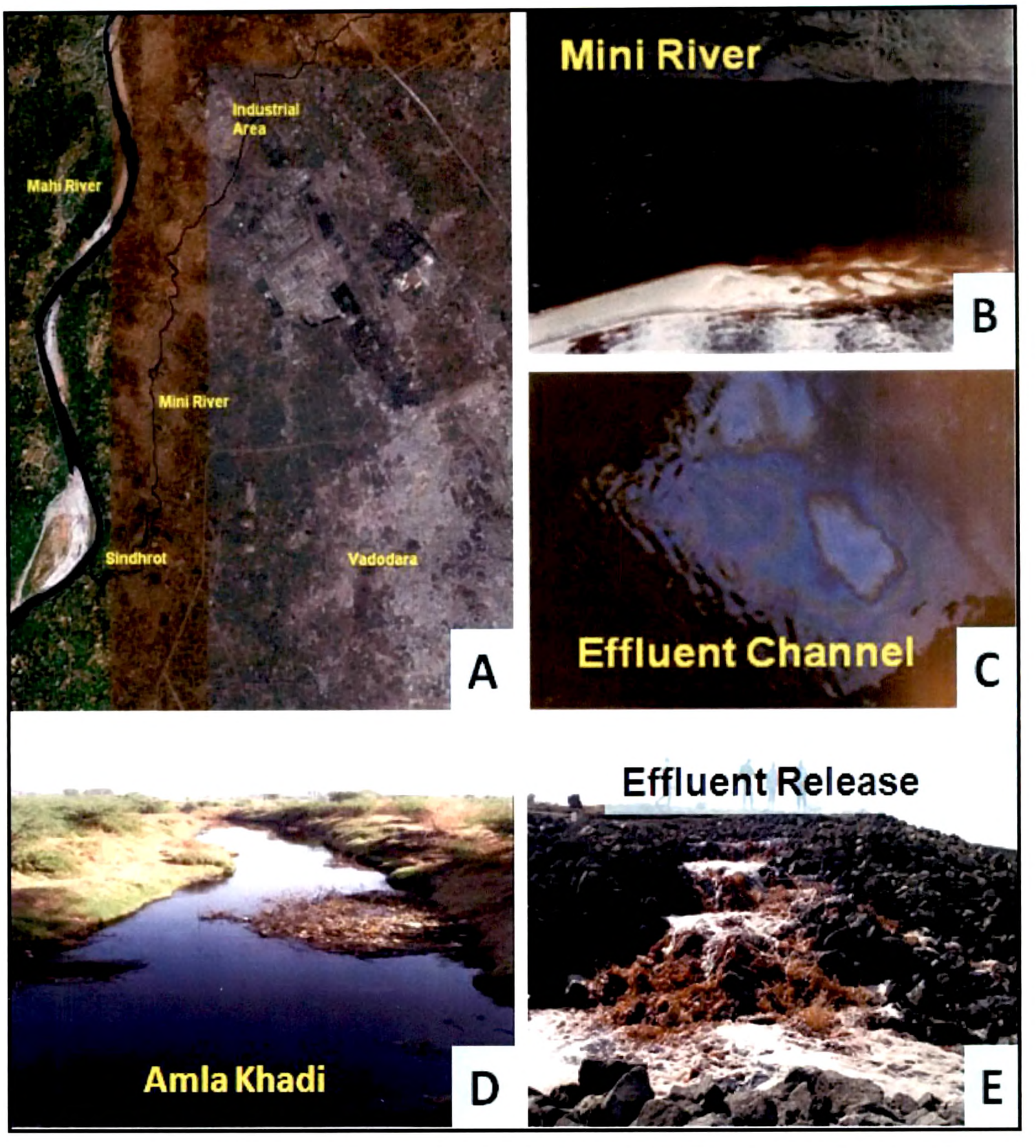


Fig. 7: Showing status of pollution in the chemical industrial zone of Gujarat. A. Mini river passing through industrial area near Vadodara and pouring into Mahi River. B. The effluent released in Mini River. C. The status of industrial effluent channel. D. Status of polluted Amla khadi. E. The effluent being released in Mahi River (location shown in Fig. 6) (A-Source: Google Earth).

Fig. 8: The pictures of air pollution being generated by the industries in the industrial area around Vadodara.

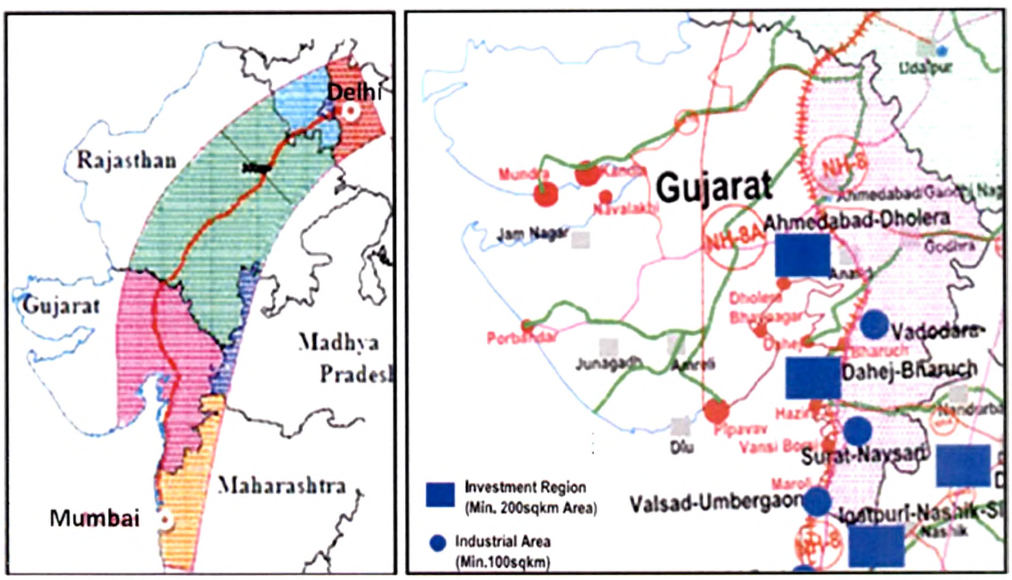
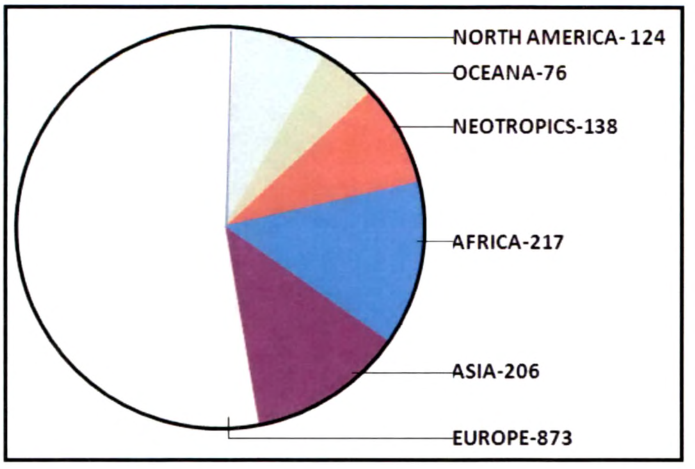
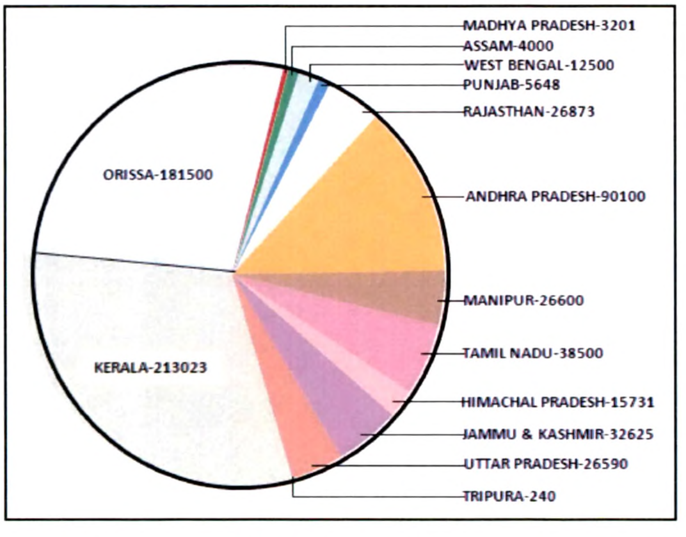


Fig. 9: Map showing the Delhi-Mumbai Industrial Corridor and the part of Gujarat where associated development is proposed.



MOEF (Ministry of Environment and Forests), 2007

Fig. 10: Regional distribution of Ramsar sites in terms of numbers at global level.



MOEF (Ministry of Environment and Forests), 2007

Fig. 11: State-wise area of Ramsar sites in India (in Ha)

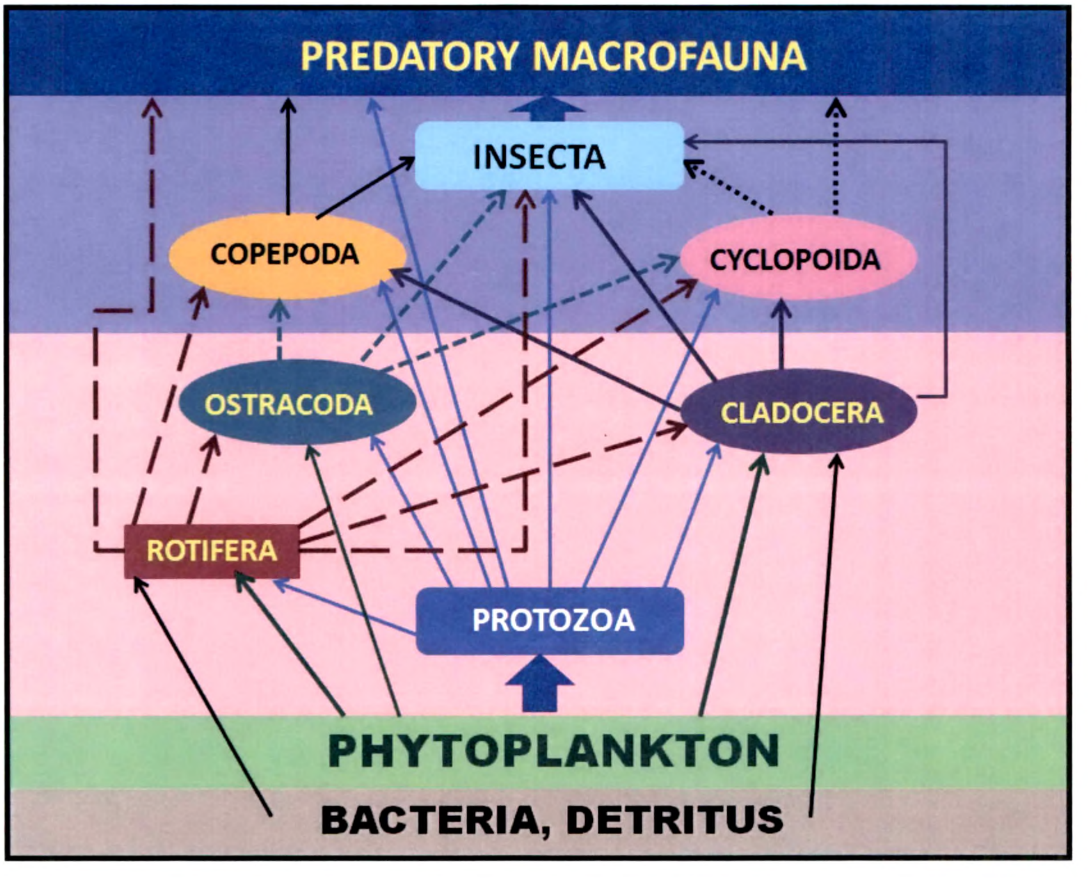


Fig. 12: Major components of the food chains operative in a lentic system.


MATERIALS AND METHODS