1. INTRODUCTION
How can we sin against water? you may say.

We can defile it. A river may be used as a water supply. It may be used as a highway. It may be used as the means to power. But the time came when it was put to a further service — it was used as a sewer.

JOHN STEWART COLLIS.

The Moving Waters.

Rupert Hart-Davies, London, 1955
Pollution in its broadest sense is the befouling of the environment by man's activities, particularly by the disposal of solids, gaseous and liquid waste products. With the increasing variety and quantity of waste products and the interlinkage among solids, gaseous and liquid states, the hazard of stream pollution is great. Gross pollution that seriously interferes with beneficial uses of water resources is unnecessary, controllable and manageable by scientific and engineering methods. However, complete elimination is impossible and some degree of pollution is inevitable. It is a normal consequence of the growth of organisms including man in or near the aquatic habitats.

Inherently, water is a multiple use resource; at the same time world is in a technological race. Parallel to the industrial expansion is the current unprecedented population growth and as the pressure of urban industrial complex increases, competition for the limited water resources intensifies among potential uses: irrigation, recreation, power generation, community and industrial water supply, navigation, carrying away of pollution load and fish. These have lead to an inevitable necessity of
ultimately disposing of the residual wastes.

Water acts as a solvent for pollutants; it can assimilate waste to a certain degree, and restore its quantity before reaching to a polluted state. Thus water pollution is significant only when it puts the ecosystem out of balance and endanger living organisms either directly or indirectly.

In the natural cycle there is no waste in the sense of loss; each living thing borrows its substances briefly only to the inanimate store house and itself be reused by countless generations. Man makes a very inefficient use of natural resources, in the process creates a colossal amount and variety of waste products. Inevitably, they are unwanted and unprofitable and large fraction is discarded as waste products. Some are dumped on soil banks, some are burnt, with end products exhausted to the atmosphere, some are buried, some are promiscuously scattered in cities and over the countryside, and an increasing amount is discharged into the intricate water carriage systems and ultimately reaches streams, rivers, lakes and estuaries.
Among, urban, agricultural, industrial and natural the four primary sources of pollution, the major and uncontrollable one is the urban pollution. Although, the industrial waste is amenable to a high degree of control, some degree of pollution is inevitable due to its high magnitude, its wide variety of wastes and its unsatisfactory control management. Chemical fertilizers, herbicides, pesticides etc; are significant sources of pollution. It reaches the stream in various ways as soil is eroded, in the process of spray application, from spilage or from manufacture of the product. The natural source of pollution are stormwash, seepage from ground water, swamp drainage and aquatic life of a stream which result in a residual pollution.

Against a heavy load of pollution from various sources, many systems have been devised for the removal of waste matter in a particulate, suspended, colloidal and in dissolved or living state. These wastewater systems involve mechanical or hydraulic separation, chemical coagulation, chemical and physical reaction, disinfection and biochemical reactions.
The dominant hydrologic characteristics of river related to quality phenomena are stream flow, water temperature, and channel. Morphology within these characteristics, all river quality processes occur and are controlled. Low flow, high temperature, long detention time and poor mixing induce increase in biological reactions. These factors when coupled with heavy carbonaceous BOD loads from municipal and industrial wastewaters can cause severe DO depletion in rivers. The low flow periods and decreased river velocity permits increased settling and accumulation of organic matter thereby exerting a high BOD. In addition rain storms brings large quantity of oxygen-demanding organic debris into rivers, resulting in depletion of DO content.

1.2 Review of Literature

On the basis of experience with numerous rivers and estuaries in the United States, it has been concluded that a thorough understanding of the hydrologic, physico-chemical and biological regime of rivers is an essential prerequisite for interpreting river quality behaviour and thus for formulating mathematical river quality models.
In India, hydrobiological features of selected stretch of the Ganga river (Uttar Pradesh) have been studied by Ray et al., (1966) reported the presence of following organisms: Diatoms (Navicula, Nitzschia, Pinnularia, Synedra, Fragilaria, Diatoma, Cyclotella and other), Green Algae (Actinastrium, Ankistrodesmus, Pediastrum, Scenedesmus, Pandorina, Spirogyra, and other), Blue Green Algae (Anabaena, Oscillatoria, Agmenellum and other) and Rotifers.

The pH of the Ganga river water ranged from 7.5 to 8.3, Dissolved Oxygen content ranged between 5.0 to 11.0 mg/l and Temperature ranged from 16.5 to 31.5°C.

ChandraPrakash (1977) has studied the physico-chemical conditions of the Jamuna river and has mentioned the high organic enriched situation of the river at Agra city, due to wastewater discharges.

Physico-Chemical conditions of the Jamuna river in relation to plankton concentration have been studied by Ray et al., (1966). Temperature and Dissolved Oxygen recorded in the Jamuna river were in the range of 19.2 to 32.0°C and 3.1 to 8.5 mg/l respectively. Among plankton diatoms were dominating.

Chaoko et al., (1955) observed certain
hydrobiological features of the Godavari river reported that water temperature ranged from 27.5 - 36.4°C, pH varied between 7.2 to 8.3 and Dissolved Oxygen content between 1.4 to 4.5 mg/l. Phytoplankton consisted of Diatoms (Navicula, Cymbella, Gyrosigma, Synedra, Diatoma, Pinnularia, Nitzschia, Fragilaria, Cyclotella and other), Green Algae (Spirogyra, Zygnema, Ulothrix, Pediastrum and other) and Blue Green Algae (Oscillatoria, Acanthella and other). Zooplankton were Ciliates, Flagellates, Rotifers and other.

Qusim and Siddiqui (1960) made preliminary observations on the pollution of the Kali (Uttar Pradesh) river. The studies revealed that the river receives wastes through Khadarabad drain. An accident of fish mortality was observed in this river which was mainly attributed to depletion of oxygen. Further Verma and co-workers (1976) have studied the physico-chemical and Biological characteristics of the Khadarabad drain and reported that it is grossly polluted and is unsuitable for some living organisms.

Pollutional hazards in the Suvaon river (Uttar Pradesh), caused by the effluents from Balrampur
sugar factory were investigated by Banerjea et al., (1960). The studies revealed that the waste creates anaerobic conditions in the river environment which, in combination with other factors, stimulate the production of $\text{H}_2\text{S}$, a gas highly toxic for aquatic life.

Limnological survey was carried out by Bhaskaran et al., (1965) in a 21 km. stretch of the Gomti river in the vicinity of Lucknow city receiving 19.84 mgd of waste from pulp and paper factory, distillery and sewage. Further, Arora et al., (1973) have studied the physico-chemical and biological quality of the Gomti river and correlated physico-chemical conditions with biological fauna. Moreover, they have also suggested the due treatment for the effluents discharged into the Gomti river.

Organic wastes from a sugar factory and a distillery plant cause year round pollution in the small Dha river (Bihar) except the rainy season (David et al., 1966).

In the absence of adequate dilution as investigated by Motwani et al., (1956), there has developed a serious pollutional hazard in the Son river (Bihar). Author reported that highly
putrescible organic matter present in the waste, draws heavily on the oxygen budget of the stream and changes the character of the stream.

The Damodar river (Bihar), which flows through the coal belt in Bihar is also a serious pollution area. The Damodar river experiences pollution due to wastes released from a large number of industries. Gopalkrishnan et al., (1966) observed that discharges adversely affect the aquatic life.

Many industries are flanking on both sides of the Hooghly river at Culcutta (West Bengal). Bhaskaran et al., (1950) while, studying the industrial wastes disposal and sanitary conditions in the Hooghly river observed the pollution below the waste discharges. Recent studies have shown that the pollution persists up to a distance of about 1.6 km. from the outfall region in the Hooghly river (Gopalkrishnan et al., 1973). Author have also reported that effects of pollutants becoming more and more apparent, the aquatic organisms are destroyed by the pollutants.

Govindan et al., (1970) studied the pollutional
aspects of the Adyar river (Madras). They have also studied the effects of pollutants on aquatic life for the period of a year and reported the presence of variety of organisms in different polluted zones.

The Cauvery river (Tamilnadu) was investigated by Ganapati et al., (1950) have reported high TDS, SS and Cl are the sources of pollution which killed river organisms.

Observations on hydrobiological features of the Cauvery river near Bhavani town were recorded (Jhingran, 1975). The temperature of river varies from 26.0 to 30.9°C, pH ranged from 8.3 to 8.5 and DO content was found to range from 1.47 to 5.6 mg/l. Main planktonic organisms were Spirogyra, Oscillatoria, Diatoma, Cymbella, Cyclotella, Synedra, Nitzschia, Navicula, Copepode and Rotifers.

Abraham (1962) while conducting survey for observations on the hydrobiology and fisheries of the Cooum river (Tamilnadu), observed that the waste received by the river exceed its load bearing capacity on account of negligible dilution, septic conditions in the water always persist.
Effluents of the Gwalior Rayon factory created a pollutional hazard in the Chaliyar river (Kerala). A large scale fish mortality was reported by Vankatraman et al., (1966) which was attributed to highly putrescible organic matter creating almost anaerobic conditions in the river with very low or nil Oxygen.

The extensive industrial complex around Bombay discharges their wastes into the canal leading to the Kali river (Maharashtra). The pH of the Kali river goes as low as 1.2 to 1.4 (CPHEAL, 1961).

Joshi (1978) has reported a natural stabilisation of city sewage before ultimately meeting the Ganga river at Allahabad. Krishnamoorthi et al., (1972) have done investigations at Nagpur with varying degrees of pollution with specific reference to micro and macro invertebrate fauna and concluded the effects of pollutants on different fauna depends upon the quality and quantity of the wastes, discharged into the water body and the dilution factor. Rana (1977) stated that with rapid industrialisation and indiscriminate discharges of wastes, our natural water getting polluted. The degree of pollution can
be assessed by evolving characteristics of the habitat.

Besides this, in other countries, similar studies have compared the physico-chemical and biological systems of the aquatic life. Green et al., (1975) studied the effects of municipal and industrial wastes inputs on the algal growth and the chemistry of the Snake river system. Algal assays have shown a sensitive indicators. Weber et al., (1975) noticed reduced algal diversity and increased importance of few species in area affected by effluents. William et al., (1971) have studied the physico-chemical and biological quality of the Ohio river (U.S.A.) and its tributaries and have illustrated distinct differences in abundance and diversity of organisms. Abundance of certain species were found to be of most importance in evaluating the effect of pollution. Tebo (1965) illustrated that the biological data obtained for plankton, fish and benthos can tell much about the physico-chemical quality of the river. Cumberland river had a diverse organisms population similar to that found in the Ohio river (U.S.A.). Some organisms requiring a clean bottom and
relatively intolerant of pollution. Weber (1973) had measured the responses of plankton and their environment, stated that biological effects of some substance or environmental condition, and the use of organisms to detect or measure the concentration of substances or to indicate the nature of physico-chemical conditions in the environment. Williams et al., (1970) have studied the physico-chemical and biological conditions of the Klamath and Lost river (U.S.A.) to determine the effects of irrigation return water and pollution of the city, on the aquatic life. Pedro (1976) studied the hydrochemistry of the Paraná river (U.S.A.) and reported that its hydrochemistry is controlled by the nature of the rocks in the basin. Williams et al., (1962) have studied the diatoms occurrence at 73 stations of major rivers of United States. Wilson et al., (1977) observed that chironomidae live in all types of conditions of the rivers and lakes. Robert et al., (1974) studied the chemistry and biology of the Savannah river and reported that the types of organisms present and their distribution are not same in the clean water and areas that have received impact from human activities.
Gaufin et al., (1956) stated that chemical analysis can detect the presence of certain pollutants, particularly when several types of pollutants are involved and in such cases pollution should be defined in terms of biological conditions rather than by chemical standards. Beak et al., (1964) indicated that biological score from two tests compared fairly well with the results of chemical surveys, so the results of such an extensive series of chemical tests could be replaced. Gopinathan et al., (1974) have discussed some environmental changes with their relative influence on the production of phytoplankton. Rai et al., (1977) have revealed that some diatoms and blue-green algae occurs even at high organic content in water. Weber et al., (1971) have evaluated the diatoms above, below and at pollution source in river Ohio and Klamath. Stoermer (1977) reported that phytoplankton assemblage composition can furnish a valuable integrative index of water quality conditions, which is difficult to achieve by other means. John et al., (1978) stated that zooplanktons have potential values as assessors of trophic conditions. They respond quickly to environmental changes and may be effective indicator of suitable
alterations in water quality. Williams (1966) have studied the rotifers at 128 sampling stations of major rivers of the United States and concluded that differences in the abundance of dominant species appeared to be the best criterion for indicating differences in water quality or pollution. Gary (1978) reported that algal community is an important component of aquatic ecosystem and is unique water quality indicator.

Patrick (1962) pointed out that in a healthy stream, a great many species should be present and the effect of pollution seems to be a reduction in number of species, with an increasing abundance of individual species among those surviving. Kolkwitz et al., (1962) pointed out that after receiving organic load, the processes of self-purification takes in river, in downstream in which it contains different organisms. MacKenthun (1969) gave an excellent picture of the kinds and number of individuals found in stream following the introduction of organic, toxic and inert forms of pollution. He also gave a comparison of clean water forms and forms with those commonly associated with polluted water. Palmer
(1962) illustrated both clean water forms of planktons and the plankton associated with pollution. Butcher (1947) studied the relation between the biology and the polluted condition and stated that dominance of Nitzschia (diatom) is a direct result of the effect of the organic pollution. Fjerdingstad (1964) studied the river Molleaa with special reference to relation of algae to pollution. He refers the Nitzschia (diatom) "Occuring most generally in polluted waters" Palmer (1969) while compiling and rating the pollution tolerant algae found that blue-green algae, especially Oscillatoria is invariably present in organic wastes. Thus the above blue-green algae can be fully employed as an indicator of organic waste pollution. Blue-green algae mostly Oscillatoria sp. increases immediately below the discharge. Saxena (1968) suggested that members of Myxophycceas are very important because they are mainly responsible for water blooms i.e. Microcystis, Chroococcus, Spirulina, Oscillatoria, Anabaena, Nostoc and Rivularia. According to Prescott (1940) high temperature, high CO₂, nitrogen, Low DO and high HCO₃ are responsible for the growth of blue-green algae and water blooms. Nemerov (1974) reported that
a zone immediately below the source of pollution is usually characterised by a low DO, high BOD, high bacterial counts, the presence of bacteria eating Ciliates and few flagellates. Klin (1972) concluded that below the discharge Ciliates reaches to peak and then decline more gradually while, Flagellates reaching a maximum 2 miles below (3.2 kms) the effluent discharge.

The biological system, the only system, is capable of effective removal of waste matter in all states and particularly dissolved organic matter. This includes the living system, the heterotrophs supported by organic matter and autotrophs supported by inorganic compounds such as nitrogen and phosphorus.

1 : 3 Water act

The availability of good potable water has been one of the major factors, influencing the development of civilization. In India 'The Water (Prevention and Control of Pollution) Act no. 6 of 1974 has established the Central and State boards'. Boards are given powers to prohibit, the use of stream, the disposal of toxic matter etc., to restrict new discharges, existing discharges of sewage and trade effluent
and emergency measures in case of stream pollution.

1 : 4  The state of Gujarat

The state of Gujarat is situated along with West Coast of India between the latitude 20.1 and 24.7 degrees North and between the longitudes 38.4 and 74.4 degrees East. The state covers approximately 6% area of the Indian Republic and has the population of about 4% of the total population.

Gujarat state has mainly two physiographic regions namely the Gujarat main land and peninsular region. The main land consists of the alluvial valleys of the Sabarmati, Mahi, Narmada and Tapi rivers, fed by catchments extending over large area of Rajasthan and Madhya Pradesh and flowing from West and converging towards the gulf of Cambay (Fig.1).

Several rivers flow across the state and discharges into Arabian sea, gulf of Cambay and Kachchh. The Sabarmati, Mahi, Narmada and Tapi are the largest among the rivers of Gujarat. The flow of river water except Narmada and Tapi is very limited, during post monsoon period. Several weirs and dams have also been constructed across the major
rivers in the state so as to conserve the water and utilise it for irrigation.

The climate is generally hot (extreme temperature recorded - 46.7°C), dry and with clear skies for about nine months in a year. It becomes more humid with the approach of the monsoon. The maximum wind speed during the year is only 20 km/h. The average rain fall ranges from 60 to 150 cms. It is maximum during July, August during which maximum flood occurs in rivers.

Traditionally, Gujarat is one of the main regions of cotton textile industry and its ancillary engineering units. Chemical and Pharmaceutical industries have been more recent additions. On the industrial map of the India, Gujarat occupies the third position amongst all the states. About 30% of cotton textile, 95% of soda ash, and over 55% salt are produced in Gujarat.

Pollution in Gujarat

The usual consequence of such as sudden industrial and urban growth is the degradation of the environment by pollution. The facilities available
hiterto for disposal of urban community wastes and industrial wastewaters have already been overstrained. Large quantities of untreated wastewaters find their way into the stream. The total pollution load discharged into the streams of Gujarat is about 242 MGD having 134087 kg BOD per day.

1 : 5 Sabarmati river basin

The Sabarmati river is one of the biggest river of North Gujarat. It passes through the state of Rajasthan and Gujarat. It is situated between the latitude 23.75 and 25 degrees North and between the longitudes 73.3 to 73.4 degrees East. The river originates from the hills of Arvalli and meets to the gulf of Cambay. In Gujarat, it passes through Sabarkantha, Banaskantha, Mehsana, Ahmedabad, Kaira and Surendranagar districts. According to the nature of the bottom, the river can be divided into four distinct zones as follow.

1. From its origin to Bhanpur; 112 kms
   (Passes through hills and jungles)

2. Bhanpur to Dharoi; 32 kms.
   (Passes through hills, valley and narrow and wide stony beds)
3. Dharoi to Ahmedabad; 1144 kms.
   (Passes through plain broad sandy bed)

4. Ahmedabad to gulf of Cambay; 128 kms.
   (Passes through a wide sandy bed and lastly muddy bed)

The total length of the Sabarmati river basin is 416 kms., the width varies from 100 m to 300 m and the average depth varies from 30 cms to 150 cms. It covers many villages and cities. The city of Ahmedabad has the major urban and industrial establishment on its banks, which has a population of about 1,957,000 and water supply of about 323,810 litres per day. The weather of the city is dry and hot with the rain fall varies between 50 to 100 cms.

Seasonal average flow data for the survey period is given below.

The Sabarmati River Flow Data (in Cusecs)
discharged from Dharoi dam.

<table>
<thead>
<tr>
<th>YEARS</th>
<th>1927</th>
<th>1928</th>
<th>1929</th>
</tr>
</thead>
<tbody>
<tr>
<td>WINTER</td>
<td>860</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>SUMMER</td>
<td>380</td>
<td>210</td>
<td>190</td>
</tr>
<tr>
<td>Monsoon</td>
<td>15,000</td>
<td>8,000</td>
<td>1,400</td>
</tr>
</tbody>
</table>
The tributaries and subtributaries of the Sabarmati river play an important role in diluting the polluted water of river. These are Wakal, Harnav, Guhai, Hathmati and its tributaries, Khari, Vatrak (with Mazam, Shedhi, Meshwa and Mohar), Bhogavo and Navido. Of these the first three meet to the Sabarmati river before Dharoi dam (Fig. 1) while, Hathmati meets along with its tributaries before Derol bridge (Vijapur). Khari and Vatrak with its tributaries meet at Vautha village. Vautha is known as holy place because it is a confluence point of seven rivers (Sabarmati, Khari, Vatrak, Shedhi, Mazam, Meshwa and Kohar). Bhogavo and Navido meet just before the Sabarmati river enters the gulf of Cambay.

Ahmedabad is main city discharging the various wastes into the Sabarmati river. About 32 outfalls were leaking the river. Of which 19 were mixing from Eastern side and rest 13 from Western side. Effluents were mainly domestic plus textile. It is important to note here that some of the outfalls leaking into river upstream of Wasna barrage are now connected with municipal sewers. At present the
major out falls leaking into the river are:

1. Out fall of Pirana sewage treatment plant discharging treated plus excess bypass of domestic and industrial wastes in the down-stream of Wasna barrage (Fig. 2).

2. Two out falls of Wasna sewage treatment plant discharging only domestic waste, treated plus excess bypass into the river at the downstream of Wasana Narol bridge (Fig. 2).

3. Chandrabhaga nadi nala, discharging the combine wastes from board, steel tube and cement factories.

In addition to this, it is also getting polluted by, washing and printing of large quantity of cloths by washermen in river itself, which adds various types of dyes and detergents to river.

At present Ahmedabad Municipal Corporation is having two sewage treatment plants. One is at the Eastern side of the river, the Pirana treatment plant, having capacity of 72 MDD and the other one is at the western side of the river the Wasna
treatment plant having capacity of 12 MGD. Looking to the quantity of the receiving wastewaters, both the treatment plants are overstrained, hence untreated bypasses find their way into the river.