# Bio-mapping of Rivers
# - Case study Assam State

## EDITORIAL

The concept of Bio-mapping water quality of rivers in the country has been establishment by Central Pollution Control Board using Biological Water Quality Criteria (BWQC). The information from Bio-mapping helps in collection of baseline data on taxonomical distribution of benthic macro-invertebrates, which are natural indicator for water quality assessment of various rivers in a river basin. Such information can be utilized for classification and zoning of water bodies according to their level of ecological sustenance and degradation.

Bio-mapping of rivers in Meghalaya among North-Eastern states has been accomplished earlier. The findings of the studies of Bio-mapping of perennial rivers of Assam have been compared with the studies undertaken for Meghalaya State in the present issue of `Parivesh' Newsletter.

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# 1.0 INTRODUCTION

## 1.1 RIVERS BIO-MAPPING CONCEPT

The concept of water quality mapping had been initiated with the identification of beneficial uses of water in terms of primary water quality criteria. CPCB has prepared Water Quality Atlas of the Indian Rivers System on the basis of five major uses of river water such as:

a) Drinking water source without conventional treatment but after disinfection;

b) Outdoor bathing organized;

c) Drinking water source with conventional treatment followed by disinfection;

d) Propagation of wildlife, fisheries;

e) Irrigation, industrial cooling, controlled waste disposal.

The concept of bio-mapping originated alongwith use of biological system for classification and zoning of water bodies according to their level of ecological degradation.

- Bio-mapping is classification of biological water quality data of river basin in the form of a colour map of various biological classes of water bodies. Different colours such as Blue, Light Blue, Green, Orange and Red, on a river basin map indicate various grades of water quality in terms of clean, slight pollution, moderate pollution, high pollution and severe pollution in the water body respectively.

- Bio-mapping is a continuous bio-monitoring programme of river basin, which should be carried out every year to obtain information on changes in biological water quality maintaining an inventory of the biological life sustained by the river.

- Bio-mapping is carried out effectively for the rivers and tributaries of a river basin, where as bio-monitoring can be done for all surface water bodies and the water quality class can be depicted by colour comparison.

- Bio-mapping of water quality has become significantly important exercise for pollution control activities because:

  a) It gives an immediate impression of the quality of a water body, subjected to multiple designated-best-uses.
  b) It helps in the identification of water bodies, in need of improvement.
  c) To know the extent of pollution control needed for restoration of water quality.

d) To collect the information on long-term cumulative effects of all adverse environmental factors.
e) To maintain and restore the ecological sustainability of the water body in terms of its wholesomeness.
f) Action plans can be prepared by simple colour comparison of the colour maps of water quality drawn for previous years.
g) It may also help in performing the formulation of national pollution control programme.

## 1.2 RIVERS BIO-MAPPING TECHNIQUES

- Benthic macro-invertebrates are the best suitable biological marker among the biotic communities in an aquatic ecosystem for bio-mapping.
- Locations on a river basin map are selected for biological sampling.
- Biological sampling is undertaken at about 0 to 5 cm depth of bottom substratum layer with the help of nets, shovels, dredges, artificial substratum etc.
- Taxonomic identification of benthic macro-invertebrates up to family level is undertaken at sampling locations itself.
- Collection of relevant environmental information according to field protocols.
- Biological water quality evaluation by – a) Saprobic score; b) Diversity score.
- Assigning the water quality class to each sampling location with respect to combinations of saprobic and diversity score of benthic macro-invertebrates collected from selected sampling locations.
- Biological water quality assessment with the help of Biological Water Quality Criteria (BWQC).
- Translating the biological water quality class of each location on river basin map to respective colours assigned in BWQC.
- Grouping the benthic macro-invertebrate families collected from various locations of river stretch with respect to Biological Water Quality Class and Indicator Colours.

## 1.3 BIOLOGICAL WATER QUALITY CRITERIA (BWQC)

This BWQC criteria is based on the range of saprobic values and diversity of benthic macro-invertebrate families with respect to water quality (Table 1). To indicate changes in water quality according to pollution levels, the taxonomic groups of benthic macro-invertebrate families with their saprobic score range from 0 to 10, in combination with the range of diversity score from 0 to 1 have been classified into five different classes. The abnormal combination of saprobic score and diversity score indicates sudden change in environmental conditions and poor substratum of water body.

**Table 1: Biological Water Quality Criteria (BWQC)**

| S. No. | Taxonomic groups | Range of saprobic score (BMWP) | Range of Diversity Score | Water quality Characteristic | Water quality Class | Indicator Colour |
|---|---|---|---|---|---|---|
| 1. | Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Diptera | 7 and more | 0.2 - 1 | Clean | A | Blue |
| 2. | Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Planaria, Odonata, Diptera | 6 – 7 | 0.5 - 1 | Slight Pollution | B | Light blue |
| 3. | Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Odonata, Crustacea, Mollusca, Polychaeta, Coleoptera, Diptera, Hirudinea, Oligochaeta | 3 – 6 | 0.3 - 0.9 | Moderate Pollution | C | Green |
| 4. | Mollusca, Hemiptera, Coleoptera, Diptera, Oligochaeta | 2 – 5 | 0.4 & less | Heavy Pollution | D | Orange |
| 5. | Diptera, Oligochaeta<br>No animals | 0 – 2 | 0 - 0.2 | Severe Pollution | E | Red |

## 2.0 BIO-MAPPING OF IMPORTANT PERENNIAL RIVERS OF ASSAM STATE

The North-Eastern state of Assam is generously endowed with water resources. The project on Bio-mapping of important perennial rivers of Assam State had been initiated at following rivers in the state since April, 2003:

- The Brahmaputra River
- The Buridihing River
- The Disang River
- The Jhanji River
- The Dhansiri River
- The Elenga Beel System Pond
- The Subansiri River
- The Borak River

Information regarding the sources, the districts through which the rivers flow and name of the major industries on their banks are given in the Table 2:

**Table 2: Major river systems, their origin and flow pattern of various rivers of Assam State**

| S. No. | River | Source of the river | Confluence Point | Major Districts on the course of the river | Major industries on the course |
|---|---|---|---|---|---|
| 1. | The Brahmaputra River | The river flows through Tibet and enter India at Arunachal Pradesh United with several rivers like Dibang, Lohit, Siang, Kundil etc. and flows through the Assam Valley to fall in the bay of Bengal | Bay of Bengal | Tinsukia, Dibrugarh, Dhemaji, North Lakhimpur, Sibsagar, Jorhat, Golaghat, Sonitpur, Darrang, Nagaon, Kamrup, Barpeta, Goalpara, Bongaigaon, Dhubri | No major industries are situated at the river bank. Guwahati Refinery at Guwahati, Kamrup discharges their treated effluent directly into the river. |
| 2. | The Buridihing River | Arunachal Pradesh | Brahmaputra at Dihingmukh | Tinsukia, Dibrugarh | Coal India Ltd., Margherita; Oil India Ltd., Duliajan; Assam Oil Division, Digboi |
| 3. | The Disang River | Arunachal Pradesh | Brahmaputra at Disangmukh | Dibrugarh, Sibsagar | Brahmaputra Valley Fertilizer, Namrup, Assam Petrochemicals Ltd., Namrup; ONGCL drilling site are located at the site of the river bank. |
| 4. | The Jhanji River | Nagaland | Brahmaputra at Jhanjimukh | Sibsagar, Jorhat | - |
| 5. | The Dhansiri River | Nagaland | Brahmaputra at Dhansirimukh | Golaghat | Numaligarh Refinery (NRL) |
| 6. | The Elenga Beel System Pond | Natural water body | - | Morigaon | HPC, Nagoon Paper Mill at Jagiroad |
| 7. | The Subansiri River | Arunachal Pradesh | Brahmaputra at Alichiga | Dhemaji, North Lakhimpur | Construction of 2000 MW National Hydroelectric Power Corporation is going on |
| 8. | The Borak River | Manipur | Meghna | Silchar, Karimganj, Badarpur | HPC, Cachar Paper Mill at Panchgram |

## 2.1 SURFACE WATER RESOURCES AND THEIR USES

The water use status of perennial rivers of Assam is presented ahead.

| S. No. | Districts/State | City/Town/Sampling period | Surface water resources | Water use status of surface water bodies |
|---|---|---|---|---|
| 1. | Miao, Arunachal Pradesh | Miao<br>April, 2003 | River Buridihing | No human influences. |
| 2. | Assam<br>Distt. Tinsukia | Margherita<br>April, 2003 | River Buridihing | Sand recovery, bathing, washing, stone crushing unit, domestic sewage disposal through surface run offs, Tea gardens on opposite bank. |
| 3. | Assam<br>Distt. Dibrugarh | Gammon Dullang, Khowang<br>April, 2003 | River Buridihing | Grazing, bathing, run offs from upper Assam Industrial areas of oil and coal fields, vegetable farming, paddy cultivation, fishing, sand recovery, Jokai Reserve wildlife. |
| 4. | Assam<br>Distt. Sibsagar | Dihingmukh, Dibrugarh<br>April, 2003 | River Buridihing | Vegetable farming, bathing, washing, fishing, boating etc., paddy fields. |
| 5. | Assam – Arunachal Pradesh | Dillighat<br>May, 2003 | River Disang | Raw water intake for drinking water supply, raw water intake of Industrial and coal mining on opposite bank of river. Forest area, HFC Tea garden, wildlife. |
| 6. | Namrup, Assam<br>Distt. Dibrugarh | Lalpagarighat<br>May, 2003 | River Disang | Water body receives effluents of HFC, surface run offs from Namrup Industrial township, vegetable cultivation, stone collection, ferry services. |
| 7. | Sibsagar, Assam | Rajabari<br>May, 2003 | River Disang | Cattle wading, sand recovery, washing, bathing, fishing, grazing cattle |
| 8. | Sibsagar, Assam | Sepaigaon, Disangmukh | River Disang | Receives HFC effluents, vegetable cultivation, cattle wading, sand recovery, boat transport, bathing and washing activities, wildlife, paddy cultivation |
| 9. | Assam - Nagaland Border<br>Distt. Sibsagar | Amguri Tea Estate Rajabari<br>May, 2003 | River Jhanji | Vegetable, mustard farming, cattle wading, tea gardens and bamboo forest. |
| 10. | Sibsagar, Assam | Jhanji<br>May, 2003 | River Jhanji | Effluent discharge from Tuli Paper Mill (Presently closed), cattle wading, sand recovery, bathing, washing, drinking, grazing. Canals joining the water body, surface run offs from Amboori Town at opposite bank. |
| 11. | Jorhat, Assam | Jhangi Mukh, Kumargaon<br>May, 2003 | River Jhanji | Vegetable and paddy farming, boating, fishing, washing, wildlife etc. grazing animals and forest. |
| 12. | Karbi-Anglong Assam and Nagaland Border | Kesharidubi, Tengani, Nambar<br>May, 2003 | River Dhansiri | Sugarcane and maize cultivation, vegetable farming, cattle wading, boating, bathing and washing, wild life. |
| 13. | Numaligarh, Assam<br>Distt. Golaghat | Numaligarh<br>May, 2003 | River Dhansiri | Drinking water intake, sand recovery, bathing, washing, fishing, discharge of NRL (Refinery) effluents. |

| S. No. | Districts/State | City/Town/Sampling period | Surface water resources | Water use status of surface water bodies |
|---|---|---|---|---|
| 14. | Golaghat – Nagaon District Border | Dhansirimukh<br>May, 2003 | River Dhansiri | Boating, cattle wading, washing, bathing, fishing and drinking. |
| 15. | Belguri, Assam<br>Nowgong/ Morigong | Jagiroad, Belguri<br>May, 2003 | Ellenga Beel, System pond | Back flow of Jagiroad Paper Mill effluents join the beel, vegetable and paddy cultivation, washing |
| 16. | Morigaon | Jagiroad, Morigaon<br>May, 2003 | Ellenga Beel, System pond | Receives Hindustan Paper Mills effluent. |
| 17. | Assam – Arunachal Pradesh Border, North Lakhimpur | Gerukamukh<br>May, 2003 | River Subansiri | Dam construction for Hydro-electric power generation. |
| 18. | North Lakhimpur Assam | Chaowlohoaghat<br>May, 2003 | River Subansiri | Cattle wading, sand recovery, washing, bathing and fishing etc. |
| 19. | Lakhimpur Assam | Alichiga, Bordubi<br>May, 2003 | River Subansiri | Fishing, paddy farming, forestry, melon farming, cattle wading |
| 20. | Assam-Manipur Border | Phuler Tal, Jiribam<br>May, 2003 | River Borak | Tea gardens cultivation activities, cattle wading, sand recovery, washing, bathing and ferry transport, forestry. |
| 21. | Silchar, Assam | Katakhal<br>May, 2003 | River Borak | Panchgram HPC township, cattle wading, sand recovery, bathing, washing, municipal waste discharge. |
| 22. | Silchar, Assam | Badarpur ghat, Badarpur<br>May, 2003 | River Borak | HPC Panchgram effluent discharge, cattle wading, bathing, washing, fishing, drinking etc. |
| 23. | Karimganj, Assam-Bangladesh Border | Kalibarighat<br>May, 2003 | River Borak | Bathing, washing, fishing and ferry transport, cattle wading |
| 24. | Tinsukia, Assam | Sakhowa ghat<br>April, 2003 | River Brahmaputra | Ferry services, melon farming, cattle wading, transport |
| 25. | Dibrugarh, Assam | Nagagholli, Maizan | River Brahmaputra | Cultivation of tea garden, cattle wading, dredging, sand recovery, ferry ghat, fishing, transport, forestry. |
| 26. | Sibsagar, Assam | Desangmukh | River Brahmaputra | Vegetable cultivation, cattle wading, bathing, washing, fishing |
| 27. | Jorhat, Assam | Nimatighat | River Brahmaputra | Cattle wading, ferry services, bathing, washing, Kakilamukh Bird Sanctuary, Forestry |
| 28. | Golaghat, Assam | Dhanbari camp | River Brahmaputra | Sand recovery, fishing, bathing, boating etc. cultivation, forestry, discharge of NRL effluents |
| 29. | Nagaon, Assam | Bhomoraguri, Silghat | River Brahmaputra | Sand recovery, fishing, bathing, washing |
| 30. | Guwahati, Assam | Saraighat | River Brahmaputra | Ferry services, cattle wading, sand recovery, fishing, bathing, washing, boating and human settlement. |
| 31. | Bongaigaon, Assam | Goalpara near Panchratna bridge<br>May, 2003 | River Brahmaputra | Cattle wading, sand recovery, fishing, bathing, washing, drinking, ferry transport. |

| S. No. | Districts/State | City/Town/Sampling period | Surface water resources | Water use status of surface water bodies |
|---|---|---|---|---|
| 32. | Dhubri, Assam | Dhubri<br><br>May, 2003 | River Brahmaputra | Cattle wading, sand recovery, fishing, bathing, washing, cultivation. |
| 33. | Guwahati, Assam | Sadilapur near Savaighat bridge, Pandu ghat<br><br>November, 2003 | River Brahmaputra | Discharge of Refinery effluents (NRL) open defaecation, town runoffs, water discharge, vegetable cultivation, cattle wading, cremation, fishing, jetty, boating, bathing. |
| 34. | Karimganj, Assam | Badarpur ghat<br><br>November, 2003 | River Borak | Water intake of railway, sand dredging, vegetable cultivation, bathing, boating, paddy cultivation, sand recovery, fishing |
| 35. | Karimganj, Assam | Karimganj, Kalighat<br><br>November, 2003 | River Borak d/s | Fishing, vegetable cultivation, washing, bathing |
| 36. | Cachar, Assam | Kathakhal on NH-44<br><br>November, 2003 | River Borak | Vegetable cultivation, fishing, sand recovery, paddy cultivation |
| 37. | Cachar, Assam | Dilkhush Tea Estate, Opp. to Fooler Tal<br><br>November, 2003 | River Borak Upstream | Vegetable cultivation, ferry services, water intake, boating, bathing and washing, tea gardens. |
| 38. | Assam Meghalaya Border | New-Malidor, Jalalpur<br><br>November, 2003 | River Malidor | Dredging, sand recovery, stone collection. |
| 39. | Silchar – Manipur Border | Fooler Tal<br><br>November, 2003 | River Borak upstream | Ferry services, Dilkhush Tea Estate, Vegetable cultivation, bathing, washing, and drinking water intake. |
| 40. | Sonitpur, Assam | Bukagaon, Balipara<br><br>November, 2003 | River Jia-Bharali | Water Intake, cultivation, religious activities, dredging and sand recovery, fishing, bathing, paddy cultivation, and brick formation. |
| 41. | Lower Subansiri Lakhimpur, Assam | Gerukamukh<br><br>November, 2003 | River Subansiri u/s | Dredging, sand recovery, transport, stone collection from river bed and transport to dam site, fishing, washing, bathing, open defaecation, mining, drilling at upstream. |
| 42. | Arunachal Pradesh Border | Dhulumukh<br><br>November, 2003 | River Subansiri upstream | Washing, bathing, boating, drinking water for wildlife transport of the River stones by motorboats to dam construction site. |
| 43. | North Lakhimpur, Assam | Chauldhua village<br><br>November, 2003 | River Subansiri d/s | Vegetable cultivation, cattle wading, dredging, sand recovery, stone collection from River bed for road construction, boating, fishing, open defaecation, village settlement. |
| 44. | North Lakhimpur, Assam | Chauldhuaghat<br><br>November, 2003 | River Subansiri d/s (midstream) | Fishing |
| 45. | Lakhimpur, Assam | Alichiga<br><br>November, 2003 | River Subansiri d/s | Cattle wading, transport by motor boats, fishing, birds habitat, cultivation |
| 46. | Lakhimpur, Assam | Pahumara, Lakhimpur<br><br>November, 2003 | River Ranganadi | Hydro-electric power generation at upstream, paddy cultivation, cattle wading, drinking water source, dredging and sand recovery, vehicle washing, bathing, fishing and transport by boat, religious activities, idol immersion, cremations. |

| S. No. | Districts/State | City/Town/Sampling period | Surface water resources | Water use status of surface water bodies |
|---|---|---|---|---|
| 47. | Lakhimpur, Assam | Bogi Nadi, Milanpur<br><br>November, 2003 | River Boginadi | Drinking water, vegetable cultivation, cattle wading, dredging and sand recovery, bathing, washing and fishing, human settlement, paddy cultivation. |
| 48. | Assam – Arunachal Pradesh Border | Parbati Nagar, Harmutty Tea Estate Bandardua – Itanagar Border<br><br>November, 2003 | River Dikrong | Cattle wading, dredging, sand recovery, fishing, bathing, boating. |
| 49. | Sonitpur, Assam | Bhoomuraguri, Tejpur | River Brahmaputra | Vegetable, paddy cultivation, bathing, washing, fishing and boating, open defaecation, wildlife. |
| 50. | Bongaigaon, Assam | Jogighopa<br><br>November, 2003 | River Brahmaputra | Water Intake of Jogighopa Paper Mill, coal transport by ship and boats, cremation, mustard vegetable cultivation, fishing, open defaecation, paddy field, human settlement. |

## 2.2 HYDROLOGICAL STATUS AND ENVIRONMENTAL PROBLEMS

Hydrological status of a water body is an important factor, which determines the status of establishment of biological communities of Benthic macro-invertebrate families. A mature colonization of benthic macro-invertebrate communities in a water body is essential for actual water quality assessment. A number of human activities such as melon farming on River bank, cultivation, brick kilns and brick formation on catchment of river sand dredging, stone collection from river bed for road construction and stone crushers etc. are detrimental activities responsible for habitat destruction in terms of change in flow, depth, self purification capacity of water body and alteration in substratum type, which in turn determine the establishment of fauna and flora in a water body. The tributaries River Brahmaputra viz. River Buridihing, River Disang and River Subansiri possess natural substratum in their upstream reaches in Assam State. Their substratum composed of mainly Boulders, Cobbles, Pebbles and Gravel with comparatively less percentage of sand. The flow of water in these reaches ranges from 0.6 to 1.0 m/s. These habitats are suitable for biological establishments. Other rivers generally have sandy and clay substratum providing poor habitat for proper colonization of biological communities.

## Table 3: Hydrological status of perennial rivers of Assam (2003)

| S. No. | Name of Rivers | Location | District/State | Period of Sampling | Approx. Depth (Meters) | Approx. width Mts/Kmts | Approx. velocity of Flow m/s | Substratum composition | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Substratum type | Percentage approx. |
| 1. | River Buridihing | Bed camp | Miaow, Arunachal Pradesh | April, 2003 | 3.0 | 25.0 | 1.0 | Boulders<br>Cobbles | 20<br>20 |
| | | | | December, 2003 | 2.0 | 20.0 | 0.9 | Pebbles<br>Gravels | 30-40<br>20-30 |
| | | Dihing, Ferry ghat | Margherita | April, 2003 | 6.1 | 200.0 | 0.6 | Sand | 70 |
| | | | | December, 2003 | 5.185 | 200.0 | 0.4 | Clay | 30 |
| | | Gammon, Dullang | Khowang | April, 2003 | 9.15 | 115.0 | 0.5 | Sand | 70-80 |
| | | | | December, 2003 | 7.32 | 150.0 | 0.4 | Clay | 20-30 |
| | | Dihingmukh | Dibrugarh | April, 2003 | 3.66 | 80.0 | 0.4 | Sand | 70 |
| | | | | December, 2003 | 8.0 | 150.0 | 0.6 | Clay | 30 |
| 2. | River Disang | Lalpagarighat | Namrup | May, 2003 | 2.135 | 200.0 | 0.5 | Boulders<br>Cobbles | 10<br>20 |
| | | | | December, 2003 | 1.525 | 180.0 | 0.3 | Pebbles<br>Gravel<br>Clay | 10-30<br>30-40<br>20 |
| | | Dillighat | Assam-Arunachal Pradesh Border | May, 2003 | 3.355 | 200.0 | 0.6 | Boulders<br>Cobbles | 50-70<br>20 |
| | | | | | | | | Pebbles<br>Clay | 10<br>20 |
| | | Rajabari | Sibsagar | May, 2003 | 3.66 | 200.0 | 0.4 | Sand<br>Silt | 30-40<br>10 |
| | | | | December, 2003 | 3.05 | 200.0 | 0.3 | Clay | 70 |
| | | Sepaigaon Disangmukh | Sibsagar | May, 2003 | 6.1 | 200.0 | 0.5 | Sand<br>Silt | 10<br>20-30 |
| | | | | December, 2003 | 4.88 | 200.0 | 0.4 | Clay | 70 |
| 3. | River Jhanji | Amghri Tea Estate Rajabari | Assam-Nagaland Border | May, 2003 | 0.915 | 30.0 | - | Gravel<br>Sand | 40<br>40-50 |
| | | | | December, 2003 | 1.525 | 50.0 | 0.3 | Clay | 10-20 |
| 4. | River Jhanji | NH-Crossing Jhanji | Sibsagar | May, 2003 | 3.0 | 200.0 | 0.2 | Sand<br>Silt | 60<br>20 |
| | | | | December, 2003 | 4.0 | 200.0 | 0.3 | Clay | 20 |
| | | Jhanjimukh, Kumargaon | Jorhat | May, 2003 | 3.66 | 30.0 | 0.4 | Sand | 50-60 |
| | | | | December, 2003 | 3.05 | 50.0 | 0.3 | Clay | 40-50 |
| 5. | River Dhansiri | Kesharidubi Tengani, Nambar | Karbi-Anglong District Assam-Nagaland Border | May, 2003 | 4.0 | 70.0 | 0.2 | Sand<br>Clay | 50-60<br>40 |
| | | | | December, 2003 | 3.0 | 80.0 | 0.3 | Silt | 50 |
| | | NRL Jetty at NH-Crossing | Numaligarh | May, 2003 | 5.0 | 300.0 | 0.7 | Sand<br>Silt | 30<br>10 |
| | | | | December, 2003 | 5.0 | 250.0 | 0.5 | Clay | 40-60 |
| | | Dhansiri Mukh | Golaghat Nagaon District Border | May, 2003 | 3.0 | 200.0 | 0.6 | Sand<br>Silt | 40-50<br>10 |
| | | | | December, 2003 | 3.0 | 220.0 | 0.5 | Clay | 40-50 |

| S. No. | Name of Rivers | Location | District/State | Period of Sampling | Approx. Depth (Meters) | Approx. width Mts/Kmts | Approx. velocity of Flow m/s | Substratum composition | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Substratum type | Percentage approx. |
| 6. | Ellenga Beel System Pond | Belguri | Jagiroad | May, 2003 | 1.0 | 20.0 | - | Clay | 100 |
| | | | | December, 2003 | 1.0 | 20.0 | - | | |
| | | Jogiroad other sie of Bridge | Morigaon | May, 2003 | - | - | - | Clay | 100 |
| | | | | December, 2003 | 1.0 | 20.0 | - | | |
| 7. | River Subansiri<br>River Subansiri | Gerukamukh Subansiri lower HE. Project | North Lakhimpur, Assam-Arunachal Pradesh Border | May, 2003 | 6.0 | 200.0 | 0.9 | Boulders<br>Cobbles<br>Pebbles<br>Gravel<br>Sand | 20<br>10<br>10<br>20<br>30-85 |
| | | | | November, 2003 | 1-20.0 | 300.0 | 0.227 | Clay<br>Detritus | 10<br>5 |
| | | Opposite Bank of Gerukamukh | Dhulumukh Arunachal Pradesh | May, 2003 | - | - | - | Boulders<br>Cobbles<br>Pebbles<br>Sand | 5<br>5<br>30<br>60 |
| | | | | November, 2003 | 20.0 | 1.5 | 0.24 | | |
| | | Chaolohoa ghat | North Lakhimpur | May, 2003 | 4.0 | 300.0 | 0.9 | Boulders | 10 |
| | | | | November, 2003 | 1-3.0 | 250.0 | 0.18 | Cobbles<br>Pebbles<br>Gravel<br>Sand | 20<br>10-50<br>10-60<br>40-50 |
| | | | | | 0.305 | 150.0 | 0.43 | Clay<br>Silt<br>Detritus | 10<br>5<br>5 |
| | | Alichiga, Bordubi | North Lakhimpur | May, 2003 | 6.1 | 250.0 | 0.7 | Sand | 50-100 |
| | | | | November, 2003 | 1-3.0 | 200.0 | 0.15-0.25 | Clay | 50 |
| 8. | River Borak | Fooler Tal, Jiribam | Assam-Manipur Border | May, 2003 | - | - | - | Sand | 75 |
| | | | | November, 2003 | 4.0 | 250.0 | 0.13 | Clay | 25 |
| | | Kathakal on NH-44 u/s of Badarpur | Cachar / Assam | May, 2003 | 7.0 | 80.0 | 0.6 | Boulders<br>Sand<br>Clay | 30<br>30-50<br>20-40 |
| | | | | November, 2003 | 10.0 | 200.0 | 0.21 | Detritus | 10 |
| | | Badarpurghat | Karimganj / Assam | May, 2003 | 8.0 | 150.0 | 0.6 | Sand | 20-60 |
| | | | | November, 2003 | 8.0 | 400-500 | 0.13 | Clay | 40-70 |
| | | Kalibarighat | Karimganj Assam-Bangladesh Border | May, 2003 | 10.0 | 100.0 | 0.7 | Boulders<br>Pebbles<br>Sand<br>Clay | 40<br>10<br>15-20<br>20-70 |
| | | | | November, 2003 | 3-4 | 300.0 | 0.117 | Detritus | 5 |
| | | Dilkhush Tea Estate Opposite bank to Fooler Tal | Assam – Manipur Border | May, 2003 | - | - | - | Clay | 100 |
| | | | | November, 2003 | 2.0 | 250.0 | 0.23 | - | - |

| S. No. | Name of Rivers | Location | District/State | Period of Sampling | Approx. Depth (Meters) | Approx. width Mts/Kmts | Approx. velocity of Flow m/s | Substratum composition | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Substratum type | Percentage approx. |
| 9. | River Brahmaputra | Saikhowaghat | Tinsukia | April, 2003 | 9.15 | 1.609 | 1.2 | Gravel<br>Sand | 5-10<br>70-75 |
| | | | | December, 2003 | 9.76 | 1.609 | 1.0 | Clay | 20 |
| | | Nagagholli, Maizan | Dibrugarh | April, 2003 | 7.625 | 1.609 | 1.0 | Sand | 70-80 |
| | | | | December, 2003 | 6.1 | - | 1.0 | Clay | 20-30 |
| | | Desangmukh | Sibsagar | May, 2003 | - | - | - | Sand | 60 |
| | | | | December, 2003 | 8.235 | 500.0 | 1.0 | Clay | 40 |
| | | Nimatighat | Jorhat | May, 2003 | 9.0 | 400.0 | 1.0 | Sand | 70 |
| | | | | December, 2003 | 10.0 | 400.0 | 1.0 | Clay | 30 |
| | | Dhanbari Camp | Golaghat | May, 2003 | 3.965 | 2.5 | 1.0 | Sand | 70-80 |
| | | | | December, 2003 | 3.05 | 2.0 | 0.9 | Clay | 20-30 |
| | | Bhomuraguri Silighat on NH-37A | Sonitpur district | May, 2003 | 12.0 | 400.0 | 1.0 | Sand | 80-100 |
| | | | | December, 2003 | 2.0 | 2.8 | 0.18-0.30 | Clay | 20 |
| | | Saraighat Bridge Sadilapur Pandy ghat | Guwahati | May, 2003 | 20.0 | 500.0 | 1.0 | Sand | 30-90 |
| | | | | November, 2003 | 6.1-15.25 | 1.5 | 0.125 | Clay | 10-70 |
| | | Joghigopa near Panchratna Bridge on NH-37 | Goalpara Town | May, 2003 | 20.0 | 400.0 | 1.0 | Sand | 40-100 |
| | | | | November, 2003 | >100 | 2.0 | 0.142 | Clay | 0-60 |
| | | Balasur | Dhubri | May, 2003 | 3.66 | 3.0 | 1.0 | Sand | 70 |
| | | | | December, 2003 | 3.05 | - | 1.0 | Clay | 30 |
| 10. | River Malidor | Jalalpur New Malidor | Assam- Meghalaya border | November, 2003 | 0.305 | 150.0 | 0.3-0.133 | Cobbles<br>Pebbles<br>Gravel<br>Sand | 20<br>50<br>10<br>10 |
| 11. | River Jia Bhorali | Bukagaon | Balipara | November, 2003 | 10-15 | 200.0 | 0.27 | Pebbles<br>Sand<br>Clay | 10<br>80<br>10 |
| 12. | River Ranganadi | Pahumara Road Bridge on NH-52 | Lakhimpur | November, 2003 | 0.2 | 150.0 | 0.76 | Sand | 100 |
| 13. | River Boginadi | Boginadi Milanpur | Lakhimpur district | November, 2003 | 0.2-0.3 | 100.0 | 0.66 | Cobbles<br>Pebbles<br>Sand | 10<br>5<br>85 |
| 14. | River Dikrong | Harmutty Tea Estate on NH-52, near Higher Secondary School | Parbati Nagar Bandardua Assam-Arunachal Pradesh Border | November, 2003 | 0.5-1.5 | 200.0 | 0.71 | Pebbles<br>Gravel<br>Sand | 20<br>10<br>70 |

## Table 3.1: Hydrological status of perennial rivers of Assam (2004)

| | Name of Rivers | Location | District/State | Period of Sampling | Approx. Depth (Meters) | Approx. width Mts/Kmts | Approx. velocity of Flow m/s | Type of water body | Substratum composition | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Substratum type | Percentage approx. |
| 1. | River Buridihing | Dihing, Ferry ghat | Margherita | October, 2004 | 5.795 | 200.0 | 0.5 | Run<br>Depositing<br>Eroding<br>Canalized | Sand<br>Clay | 80<br>20 |
| | | Bed Camp | Miao, Arunachal Pradesh | October, 2004 | 2.5 | 30.0 | 1.0 | Run | Boulders<br>Cobbles<br>Pebbles<br>Gravel | 30<br>10<br>40<br>20 |
| | | Gammon, Dullang | Khowang | October, 2004 | 6.1 | 200.0 | 0.5 | Run<br>Eroding<br>Canalized | Sand<br>Clay | 80<br>20 |
| | | Dihingmukh | Dibrugarh | October, 2004 | 10.0 | 150-200 | 0.7 | Run<br>Depositing<br>Eroding<br>Canalized | Sand<br>Clay | 70<br>30 |
| 2. | River Disang | Lalpagarighat | Namrup | October, 2004 | 2.745 | 200.0 | 0.4 | Run<br>Depositing<br>Eroding<br>Canalized | Sand<br>Clay | 30<br>70 |
| | | Dillighat | Assam-Arunachal Pradesh Border | October, 2004 | 3.05 | 200.0 | 0.5 | Run<br>Canalized | Boulders<br>Cobbles<br>Pebbles<br>Clay | 50<br>20<br>20<br>10 |
| | | Rajabari | Sibsagar | October, 2004 | 2.745 | 200.0 | 0.4 | Run<br>Depositing<br>Eroding<br>Canalized | Sand<br>Clay | 30<br>70 |
| | | Sapaigaon Disangmukh | Sibsagar | November, 2004 | 3.66 | 200.0 | 0.5 | Run<br>Depositing<br>Eroding<br>Canalized | Sand<br>Silt<br>Clay | 10<br>20<br>70 |
| 3. | River Jhanji | Amguri Tea Estate | Assam-Nagaland Border | November, 2004 | 1.22 | 50-100 | 0.4 | Run<br>Eroding | Gravel<br>Sand<br>Clay | 40<br>50<br>10 |
| | | NH-Crossing Jhanji | Sibsagar | November, 2004 | 1.22 | 200.0 | 0.4 | Run<br>Depositing<br>Eroding<br>Canalized | Sand<br>Silt<br>Clay | 60<br>20<br>20 |
| | | Jhanjimukh, Kumargaon | Jorhat | November, 2004 | 2.745 | 50-100 | 0.3 | Run<br>Depositing<br>Eroding<br>Canalized | Sand<br>Clay | 70<br>30 |

| | Name of Rivers | Location | District/State | Period of Sampling | Approx. Depth (Meters) | Approx. width Mts/Kmts | Approx. velocity of Flow m/s | Type of water body | Substratum composition | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Substratum type | Percentage approx. |
| 4. | River Dhansiri | Kesharidubi Tengani, Nambar | Karbi-Anglong | November, 2004 | 4.0 | 100.0 | 0.4 | Run<br>Eroding<br>Canalized | Sand<br>Clay | 70<br>30 |
| | | NRL Jetty at NH-Crossing | Numaligarh | November, 2004 | 4.0 | 100.0 | 0.4 | Run<br>Eroding<br>Canalized | Sand<br>Clay | 70<br>30 |
| | | Dhansiri Mukh | Golaghat Nagaon District Border | November, 2004 | 4.0 | 250.0 | 0.4 | Run<br>Depositing<br>Eroding<br>Canalized | Sand<br>Silt<br>Clay | 60<br>10<br>20 |
| 5 | Ellenga Beel System Pond | Belguri | Jagiroad | December, 2004 | 1.0 | 20.0 | No flow | Pool<br>Depositing<br>Canalized | Clay | 100 |
| | | Belguri | Jagiroad | December, 2004 | 1.0 | 20.0 | No flow | Pool<br>Depositing<br>Canalized | Clay | 100 |
| 6. | River Subansiri | Gerukamukh Subansiri lower HE. Project | North Lakhimpur, Assam-Arunachal Pradesh Border | December, 2004 | 10.0 | 300.0 | 0.4 | Run | Pebbles<br>Sand | 20<br>80 |
| | | Opposite Bank | Dhulumukh Arunachal Pradesh | - | - | - | - | - | - | - |
| | | Chaolohoa ghat | North Lakhimpur | December, 2004 | 4.0 | 250.0 | 0.2 | Run<br>Depositing<br>Eroding<br>Canalized | Pebbles<br>Gravel<br>Silt | 30<br>60<br>10 |
| | | Alichiga | North Lakhimpur | December, 2004 | 3.0 | 200.0 | 0.4 | Run | Sand<br>Clay | 90<br>10 |
| 7. | River Borak | Fooler Tal, Jiribam | Assam-Manipur Border | November, 2004 | 5.0 | 250.0 | 0.2 | Run | Cobbles<br>Sand<br>Clay | 80<br>20 |
| | | Kathakal on NH-44 u/s of Badarpur | Cachar / Assam | November, 2004 | 8.0 | 200.0 | 0.3 | Run<br>Canalized | Cobbles<br>Sand<br>Clay | 10<br>60<br>30 |
| | | Badarpurghat | Karimganj / Assam | November, 2004 | 6.0 | 300-400 | 0.2 | Run<br>Depositing<br>Canalized | Sand<br>Clay | 30<br>70 |
| | | Kalibarighat | Karimganj Assam-Bangladesh Border | November, 2004 | 3.0 | 300.0 | 0.2 | Run<br>Canalized | Sand<br>Clay | 30<br>70 |
| | | Dilkhush Tea Estate Opposite bank to Fooler Tal | Assam – Manipur Border | - | - | - | - | - | - | - |

| | Name of Rivers | Location | District/State | Period of Sampling | Approx. Depth (Meters) | Approx. width Mts/Kmts | Approx. velocity of Flow m/s | Type of water body | Substratum composition | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Substratum type | Percentage approx. |
| 9. | River Brahmaputra | Saikhowa ghat | Tinsukia | October, 2004 | 10.675 | Very wide | 1.2 | Run<br>Eroding<br>Canalized | Gravel<br>Sand<br>Clay | 10<br>80<br>10 |
| | | Nagagholli, Maizan | Dibrugarh | October, 2004 | 6.1 | Very wide | 1.0 | Run<br>Eroding<br>Canalized | Sand<br>Clay | 80<br>20 |
| | | Desangmukh | Sibsagar | November, 2004 | 9.15 | 500-700 | 1.0 | Run<br>Eroding<br>Canalized | Sand<br>Clay | 70<br>30 |
| | | Nimatighat | Jorhat | November, 2004 | 15.0 | Very wide | 1.0 | Run<br>Eroding<br>Canalized | Sand<br>Clay | 80<br>20 |
| | | Dhanbari Camp | Golaghat | November, 2004 | 3.05 | Very wide | 1.0 | Run<br>Eroding<br>Canalized | Sand<br>Clay | 80<br>20 |
| | | Bhomuraguri Silighat on NH-37A | Sonitpur district | November, 2004 | 3.0 | 2 km | 0.4 | Run<br>Eroding<br>Canalized | Sand<br>Clay | 90<br>10 |
| | | Saraighat Bridge Sadilapur Pandu ghat | Guwahati | December, 2004 | 4.575 | Very wide | 0.2 | Run<br>Depositing<br>Eroding<br>Canalized | Sand<br>Clay | 80<br>20 |
| | | Joghigopa near Panchratna Bridge on NH-37 | Goalpara Town | December, 2004 | 1.0 | 20.0 | No flow | Depositing<br>Canalized | Clay | 100 |
| | | Balasur | Dhubri | November, 2004 | 3.05 | Very wide | 1.0 | Run<br>Eroding<br>Canalized | Sand<br>Clay | 80<br>20 |
| 10. | River Malidor | Jalalpur | Assam- Meghalaya border | November, 2004 | - | 100.0 | 0.2 | Run<br>Canalized | Boulders<br>Cobbles<br>Pebbles<br>Gravel | 20<br>20<br>40<br>20 |
| 11. | River Lubha | Near Lubha bridge | Sonapur, Meghalaya | November, 2004 | 2.0 | 80.0 | 0.4 | Run<br>Canalized | Boulders<br>Cobbles | 80<br>20 |

## Table 4: Environmental Problems related to various activities in vicinity of Perennial Rivers in Assam

| S. No. | Rivers/Water bodies | Location of Stretch | Activities | Environmental Problems |
|---|---|---|---|---|
| 1. | River Buridihing | Bed camp at Miao in Arunachal Pradesh | Forest Miaow, stone collection from catchment of River, Birds habitat | Habitat destruction due to stone removal from riverbed. |
| | | Dihing, ferry ghat at Margherita | Sand recovery, bathing, washing, urban activities, grazing, stone crusher units, Tea gardens, surface drainage discharge. | Habitat destruction due to stones removal for stone crushing, silting in river, nutrient run offs through tea garden and sewage discharge affect water quality. |
| | | Gammon, Dullang at Khowang, NH-37 | Grazing, farming, bathing, activities of upper Assam Industrial area of Oil and Coal fields, vegetable, paddy cultivation, fishing, sand recovery, Jokai Reserve Wildlife, forest. | Industrial activities affect the water and air quality and sensitive zone of wildlife reserve. |
| | | Dihingmukh at Dibrugarh | Vegetable farming, bathing, washing, fishing, boating, paddy fields, human settlement | Silting in water body through surface run offs, water quality gets affected. |
| 2. | River Disang | Dillighat at Assam-Arunachal Pradesh Border | Drinking water supply Industrial and Coal mining activities, Tea gardens, wildlife. | Water quality affected due to surface run offs from Industrial and Coal mining activities and Tea gardens. |
| | | Lalpagari ghat at Namrup Industrial Township | Activities of Industrial township of Namrup. Vegetable cultivation, stone collection, ferry transport of Hindustan Fertilizer Corporation. | Habitat destruction due to stone removal from Riverbed, silting in water body through surface run offs, water quality affected due to HFC effluents. |
| | | Rajabari, Sibsagar | Cattle wading, sand recovery, washing, bathing and fishing. | Silting in water body from surface run offs. |
| | | Sepaigaon, Disangmukh, Sibsagar | Vegetable cultivation, cattle wading, sand recovery, boat transport, bathing, washing wildlife, paddy fields, human settlement. | Silting in water body, fish kills reported by villagers. Water quality affected due to HFL effluent discharge. |
| 3. | River Jhanji | Amgwa Tea Estate, Rajabari Assam-Nagaland border | Nagaland Paper Mill (presently un-operated), vegetable, mustard, Tea garden, cultivation in catchment, bamboo forest, deforestation. | Muddy colour water, silting in water body through surface runoff. Deforestation due to use of bamboo as raw material for paper manufacturing. |
| | | NH-Crossing, Jhanji at Sibsagar | Tuli Paper Mill (Presently unoperated) cattle wading, sand recovery, bathing, washing, drinking etc. grazing land etc. | Water quality problems. |
| | | Jhanjimukh, Kumargaon at Jorhat near Teok | Vegetable and paddy farming, boating, fishing,, washing, boating wildlife. | Habitat destruction for wildlife. |

| S. No. | Rivers/Water bodies | Location of Stretch | Activities | Environmental Problems |
|---|---|---|---|---|
| 4. | River Dhansiri | Kesharidubi, Tengani Nambar, Assam-Nagaland border | Sugarcane, vegetable and maize cultivation in the catchment, cattle wading, boating, bathing, washing wildlife. | Habitat destruction for wildlife. |
| | | NRL Jetty at NH-Crossing, Numaligarh | Numaligarh Refinery activities, drinking water intake, sand recovery, bathing, washing, fishing, discharge of NRL effluents. | Water quality problems. |
| | | Dhansirimukh, Golaghat, Nagaon District border | Wildlife of Kaziranga National Park, receiving NRL effluents, cattle wading, washing, bathing, fishing and drinking. | Drinking water quality problems. |
| 5. | Elenga Beel System Pond | Belguri, Jagi Road | Jagi Road Paper Mill, vegetable and paddy cultivation, washing. | Water quality problems due to discharge of Paper Mill effluents. Deforestation due to use of bamboo as raw material for paper manufacturing. |
| | | Jagiroad, other side of bridge, Morigaon | HPC Jagiroad activities. Deforestation of Bamboo forest | Discharge of effluents of Hindustan Paper Mill effluents, water quality problems. |
| 6. | River Subansiri | Gerukamukh, Subansiri Lower H.E. Project, North Lakhimpur District | Dam construction activities for Hydroelectric power generation project of NHPC, Deforestation, extensive sand, stone dredging activities, sand recovery, transport of river stones by motor boats to dam site, fishing, washing, bathing, open defaecation, mining, drilling at dam site. | River Bed habitat destruction, silting in water body, loss of biodiversity, poor quality of road, national highway due to use of river stones, silting on vegetation. |
| | River Subansiri u/s | Dhulumukh, Arunachal Pradesh border | Washing, bathing, boating, drinking water for wildlife, river stones transport to dam site on motor boats, mining and drilling of NHPC on dam site. | River Bed habitat destruction, loss of biodiversity, silting in water body. |
| | River Subansiri m/s | Chaowldhoa ghat N. Lakhimpur | Cattle wading, sand recovery, washing, bathing, fishing, vegetable cultivation, dredging, river bed stones are removed for road construction, open defaecation grazing, forest, village settlement. | River bed habitat destruction, water quality problems, silting in water body. |
| | River Subansiri d/s | Alichiga | Deforestation, cattle wading, transport by motor boats, fishing, boating, birds habitat, pumping river water for cultivation. | Soil erosion of river banks water quality problems doe to surface run offs. Habitat destruction for resting birds. |
| 7. | River Ranganadi | Pahumara Lakhimpur | Ranganadi Hydal Project of NEPCO, Kemang in Arunachal Pradesh, settlement of Bamundaloni village on the bank of river paddy cultivation, cattle wading, drinking water, dredging, sand recovery, vehicle washing, bathing, and fishing, transport by boat, religious activities, idol immersion, cremation etc. | Silting in water body, water quality problems. |
| 8. | River Boginadi | Boginadi Milanpur Lakhimpur District | Drinking water for local residents, village settlement on the River bank, vegetable cultivations, cattle wading, dredging, sand recovery, stone collection from river bed, bathing, washing and fishing, grazing, paddy cultivations. | Water quality problems through surface run offs. Rive bed habitat destruction. |

| S. No. | Rivers/Water bodies | Location of Stretch | Activities | Environmental Problems |
|---|---|---|---|---|
| 9. | River Dikrong | Parbati Nagar Bandardua | Tea estate on opposite bank, cattle wading, dredging, sand recovery, fishing, bathing, boating, river stones, removed for construction material, grazing land, paddy cultivation. | Water quality problems through surface run offs. Riverbed habitat destruction. Silting in water body. |
| 10. | River Barak | Fooler Tal, Jiribam Assam-Manipur border | Ferry services, Tea gardens, cattle wading, sand recovery washing, bathing, forestry. | Water quality problems due to surface run offs. Silting in water body. |
| | | Fooler Tal opposite bank, Dilkhush Tea estate | Water Intake, vegetable cultivation, transport by ferry service, boating, bathing, washing, Tea gardens | Silting in water body, water quality due to surface run offs. |
| | | Badarpur, Badarpurghat | Construction of new railway bridge, water intake of railways, vegetable cultivation, bathing, boating, paddy cultivation, dredging and sand recovery, discharge of HPC effluents, deforestation of bamboo forest. | Water quality problem, habitat destruction of riverbed. Deforestation due to use of bamboo as sole raw material for paper manufacturing, silting in water body. |
| | | Kalibarighat, Karimganj, Assam-Bangladesh border | Bathing, washing, fishing, ferry transport cattle wading, religious activities, BSF camp water intake of Bangladesh, vegetable cultivations, solid waste disposal. | Water quality problems, water hyacinth. |
| | | Kathakhal, Silchar | Sewage discharge of township Panchgram Hindustan Paper Mill, cattle wading, sand recovery, bathing, washing, fishing, vegetable, paddy cultivation. | Water quality problems, habitat destruction of river catchment. |
| 11. | River Malidor | New Malidor, Jalalpur, Assam-Meghalaya Border | Stone crushing, stone collection from river bed and transport by truck, deforestation, dredging, sand recovery. | Habitat destruction of river bed silting in water body. |
| 12. | River Jiabharali | Bukagaon, Balipara Division | Water intake for drinking water supply, cultivation, religious activities, dredging, sand recovery, fishing, bathing, paddy cultivation, brick kiln. | Water quality problems due to surface run offs, habitat destruction of river catchment. |
| 13. | River Brahmaputra | Saikhowaghat, Tinsukia | Ferry services, melon farming, cattle wading | Soil erosion, silting in water body, floods, sandy substratum. |
| | | Nagagholli, Maizan, Dibrugarh | Tea garden, cattle wading, dredging, sand recovery, ferry ghat, fishing & transport. | Water quality problems through surface run offs, floods, sandy substratum |
| | | Desangmukh, Sibsagar | Vegetable cultivation, cattle wading, bathing, washing, fishing | Floods, sandy substratum. |
| | | Nimatighat, Jorhat | Ferry services, bathing, washing, Kakilamukh Bird's sanctuary | Floods, sandy substratum. |
| | | Dhanbari Camp, Golaghat | Sand recovery, fishing, bathing, boating, cultivation, NRL effluent discharge. | Water quality problems, floods, sandy substratum. |
| | | Bhomoraguri Silighat, Sonitpur District | Sand recovery, fishing, bathing, washing, vegetable, paddy cultivation, open defaecation, Kala Bhomoraguri wildlife, Teak forest, deforestation. | Floods, soil erosion, tree falling due to desilting, habitat destruction. |
| | | Saraighat, Sadilapur, Guwahati | Discharge of Guwahati Refinery effluent, ferry services, cattle wading, sand recovery, bathing, washing, fishing & human settlements, Town, run offs vegetable cultivation open defaecation. | Water quality problems, sandy substratum. |
| | | Jogighopa near Panchratna bridge Golpara | Bongaigaon industrial township, coal storage on the river bank and transport of coal through motor boats, cremation ground, cultivation, fishing, open defaecation, water intake of Joghighopa Paper Mill, Paddy fields, coal depot, human settlements, brick kiln. | Water quality problems, soil erosion, sandy substratum, habitat destruction of river bank, use of bamboo as sole raw material for paper manufacturing, deforestation in the area. |
| | | Dhubri | Bongaigaon on the opposite bank, cattle wading, washing, sand recovery, fishing, bathing. | Floods |

**Table 5: Water Quality Status of River Brahmaputra & its Tributaries**

| S. No. | Parameters | | Values | Location |
|---|---|---|---|---|
| 1. | pH | Average | 7.44 | - |
| | | Minimum | 5.44 | Buridihing at Margherita |
| | | Maximum | 11.2 | Elenga Beel at Jagi Road |
| 2. | Conductivity (µmhos/cm) | Average | 272.13 | - |
| | | Minimum | 48.0 | River Borak at Panchgram |
| | | Maximum | 2590.0 | Elenga Beel at Jagi Road |
| 3. | DO (mg/l) | Average | 6.29 | - |
| | | Minimum | 0.6 | Elenga Beel at Jagi Road |
| | | Maximum | 10.3 | River Subansiri at Gerukamukh |
| 4. | BOD (mg/l) | Average | 4.13 | - |
| | | Minimum | 0.3 | River Borak at Panchgram |
| | | Maximum | 46.0 | Elenga Beel at Jagi Road |
| 5. | Chloride (mg/l) | Average | 27.5 | - |
| | | Minimum | 2.0 | River Borak at Panchgram, River Disang at Gudamghat, R. Brahmaputra at Pandughat |
| | | Maximum | 406.0 | Elenga Beel at Jagi Road |
| 6. | Total Dissolved Solids (mg/l) | Average | 210.36 | - |
| | | Minimum | 46.0 | River Disang at Gudamghat |
| | | Maximum | 1718.0 | Elenga Beel at Jagi Road |
| 7. | Sulphate (mg/l) | Average | 23.81 | - |
| | | Minimum | 0.72 | River Subansiri at Gerukamukh |
| | | Maximum | 175.2 | Elenga Beel at Jagi Road |
| 8. | Nitrate (mg/l) | Average | 0.309 | - |
| | | Minimum | BDL | River Brahmaputra at Maizan |
| | | Maximum | 2.25 | River Disang at Gudamghat |
| 9. | Boron (mg/l) | Average | 1.218 | - |
| | | Minimum | BDL | 10 times out of 22 observations |
| | | Maximum | 2.37 | River Borak at Panchgram |
| 10. | Amm. Nitrogen (mg/l) | Average | 0.049 | - |
| | | Minimum | BDL | 10 times BDL, 10 times in Traces |
| | | Maximum | 1.0 | Elenga Beel at Jagi Road |
| 11. | Total coliforms MPN/100 ml | Average | - | - |
| | | Minimum | 300.0 | River Buridihing at Margherita |
| | | Maximum | 24,000 | River Disang, Elenga Beel, River Borak and River Dhansiri |
| 12. | Faecal coliforms MPN/100 ml | Average | - | - |
| | | Minimum | 30.0 | River Dhansiri at Golaghat |
| | | Maximum | 14,000 | River Disang at Gudamghat |

BDL = Below detection limit

## 2.3 PERENNIAL RIVERS OF ASSAM – LOCATION AND MORPHOLOGICAL FEATURES

*RIVER BURIDIHING*

River Buridihing is major tributary of the Brahmaputra in Assam, which arises from the eastern part of Assam and Arunachal Pradesh border.

*a. River Buridihing at Bed Camp, Miao (Arunachal Pradesh)*

This sampling site is located at upstream of River Buridihing at Miao in Arunachal Pradesh. There is not much human influence on water body except for the removal of River bed stones. The water body is covered on both the banks by Miao Forests.

*b. River Buridihing at Dihing Ferryghat, Margherita*

The sampling location on Buridihing River is situated on the border of Assam at Margherita near the Railway bridge and NH Road bridge. Margherita is located at downstream of coal mining activities. Hillocks are present on the opposite bank of River. The catchment of opposite bank is covered with Tea gardens. The water body gets influenced by several human activities after entering the Assam border. N.E. Coalfields of Tikak, Tirap etc. are situated upstream of this location.

*c. River Buridihing at Gammon, Dullang at Khowang*

The sampling site of River Buridihing at Khowang is located near National Highway No. 37. The water body has crossed the entire Upper Assam Industrial areas of Oil and Coal fields. Jokai Reserve Wildlife is located in vicinity of sampling location.

*d. River Buridihing at Dihingmukh, Dibrugarh*

At downstream of this location, River Buridihing joins River Brahmaputra, a number of small streams join River Buridihing. Wild Ducks and common birds are quite often observed at this location.

*RIVER DISANG*

River Disang is another major tributary confluencing with the River Brahmaputra at its south bank carrying discharge of Namrup Fertilizer and Assam Petrochemicals Ltd. and its basin covers the catchment area of ONGC Ltd. activities in Sibsagar District. The Disang River originates from Patki Bunn (Naga Hills). The maximum altitude near the source is 2594.15 mtr. The Tisa (original name of the river) after moving 60.8 km towards north, meets its first tributary Towaizo. The combined flow moves further north and meets tributary Tiratjo.

Moving further north, the river appears in the plains near Namrup, a place of historic as well as of industrial importance (Nam means water and rup means silver). The name refers to water shining like silver. From Namrup, the River flows towards north – western direction through the plains of Dibrugarh District. The River flows through the alluvial plains of Dibrugarh and Sibsagar District. After flowing further in west-south-west direction to about 86.4 km, the River meets another tributary Bor Timak Nadi, which originates from the foothills, on the left bank. After crossing a distance of about 22.4 km towards south-west, the River meets, with main tributary Safrai then passes through Nangala – maraghat and turns north. Following a further course, river meets the Diroi and the Dimou tributaries on its right bank. Finally, the river meets Brahmaputra, after a total course of 572 km (including the course of tributaries) near Disangmukh at a distance of 11.2 km from the sub-divisional town Sibsagar.

a. *River Disang at Dillighat*

Dillighat is the starting point of River Disang at Assam-Arunachal Pradesh Border. At this location, river Disang enters into plains towards upstream of Namrup industrial area. The water body possess pristine water quality at this locations. The coal mining areas are located on the opposite bank of River. The sampling station is located towards coal mining site. Water intake for drinking water supply is towards Arunachal Pradesh. The water intake point is surrounded by Forest and HFC. Tea gardens are located on either side of Dillighat Bridge on River Disang. The area inhabits wildlife such as Tiger, Deer, wild Boar and Elephant. This stretch of river is used for drinking without treatment.

b. *River Disang at Lalpagri Ghat, Namrup*

The River Disang passes through the Namrup Industrial township before reaching to this location, the River gets all possible effluent drains from industrial town and municipal waste. HFC effluents are also discharged in the River. The sampling site is located near Bamboo bridge. This stretch of River Disang is used for outdoor bathing. Namrup Tea estate is also situated in the vicinity of this location.

c. *River Disang at Rajabari, Sibsagar*

The sampling site is located by the side of the NH-37. Sibsagar, Rajabari and Dimow towns are located on the bank of River around this location. The opposite bank of River is a grazing land. ONGC drilling operation is done at upstream of Bhojo. An important tributary River Diroi joins River Disang at National Highway crossing.

*d.* *River Disang at Disangmukh, Sibsagar*

This is the end point of the River before mixing with the Brahmaputra. Tea gardens are located in nearby areas. The sampling stations on River Disang is located at Sapaigaon. Wild ducks, common birds and wild elephants are often observed at this location. Fish kills are often reported by villagers.

*RIVER JHANJI*

*a.* *River Jhanji*

River Jhanji originates from hills of Nagaland and flows through upper Assam. Jhanji river is one of the major south bank tributaries joining at the middle stretch of the River Brahmaputra. Earlier, the river Jhanji used to carry the discharge from the Tuli Paper Mill at Nagaland. River Jhanji arises from Naga hills and enters Assam-Nagaland border at Tuli where the Nagaland Paper Mills is located. Bamboo forests surrounds the Tea garden surrounding the sampling location. Amghri Tea Estate is located on the opposite bank of River towards Nagaland border.

*b.* *River Jhanji at Amguri Tea Estate, Rajabari*

At this location River Jhanji enters the border of Assam from Nagaland. Amguri Tea Estate is located on the opposite bank of River towards Nagaland border.

c. River Jhanji at Sibsagar

The sampling site on River Jhanji was selected at NH-37 crossing of Jhanji. Earlier at this location River Jhanji carried the wastewater discharge from Tuli Paper Mills in Nagaland. Now this industry is not operational.

d. River Jhanji at Jhanji Mukh, Jorhat

River Jhanji joins River Brahmaputra at upstream of this location at Kumargaon near Teok. The surrounding land is used for grazing and forest.

*RIVER DHANSIRI*

A major south bank tributary to the river Brahmaputra flowing through Golaghat District and supposed to carry the discharge from Numaligarh refinery. River Dhansiri rises from Karbi-Anglong District of Assam and Nagaland Border.

a. *River Dhansiri at Keshardubi*

The sampling site on River Dhansiri is located near the bamboo bridge across the River connecting villages of Tengani and Nambar etc. Sampling site at Keshardubi is situated in between Dimapur and Golaghat. The opposite bank of River Dhansiri is closed to Nagaland and North Cachar Hills. Wildlife of Elephant, Tiger and Deer are found in this area.

b. *River Dhansiri at NRL Jetty, Numaligarh*

The sampling site is near Jetty of Numaligarh Refinery Ltd. (NRL) at NH-Crossing. NRL effluents are discharged here.

c. *River Dhansiri at Dhansirimukh*

Dhansirimukh is the confluence point to River Brahmaputra. The sampling site on river Dhansiri was selected before confluence at boating ghat near Golaghat and Nagaon District border. Common birds and wild ducks are observed here. Surrounding land is used for grazing. Kaziranga National Park ranges are located towards Nagaon on the riverbank. Sampling site is towards Golaghat bank.

*ELLENGA BEEL SYSTEM POND*

This is a beel system with low lying lands and becomes a small rivulet in lean season but during rainy season the entire low lying area becomes inundated and takes the shape of a beel. This system receives ETP discharge and wastewater from Nagaon Paper Mill of HPC Ltd. Two drains from the paper mill containing different types of sludge ultimately reach the beel systems and causes siltation problem. The water quality of this beel reach the River Kapili / Kalong as a small stream.

a. *Ellenga Beel at Belguri, Jagiroad*

The water body is stagnant in the village area. Vegetable and paddy cultivation is done in the vicinity. Water hyacinth growth throughout the surface of water body. Surrounding land is covered by forest Kapili River flows in close vicinity.

b. *Ellenga Beel System Pond, Jagiroad, Morigaon*

This is a vast ecosystem comprising beel water. The site is nearby the HPC Nagaon Paper Mill outlet. Sampling site was selected on the other side of bridge on Elenga beel system pond towards HPC Jagiroad. Water Hyacinth grows throughout the water body.

## *RIVER SUBANSIRI*

This River is one of the major north bank tributaries of Brahmaputra. The River enters into Assam to confluence with the River Brahmaputra after flowing through the hills and forest of Arunachal Pradesh. Dam construction of NHPC is the major activity here. Dam is yet to be constructed. The surrounding of opposite bank is covered by forest. Subansiri is named due to having gold in its sand many years ago.

*a. River Subansiri at Gerukamukh*

The sampling site on River Subansiri is located at Gerukamukh Subansiri lower Hydro-electric project, near Kendriya Vidyalaya, and between upstream of stone bridge under construction on river and downstream of dam site. NHPC, HE project of 2000 MW is under construction. Earlier the entire area was under Brahmaputra Board. Three months ago the area was inhabited by township, which was taken over by NHPC. Now NHPC township exists alongwith schools and medical centre with 20 beds. Dept. of Forest of Assam Govt. takes care of afforestation activities.

*b. River Subansiri at Dhulumukh*

Dhulumukh is located in Arunachal Pradesh towards opposite bank of Gerukamukh. Extensive stone harvesting from River bed of Subansiri is carried out transporting through motor boats towards Dam site, where mining and drilling of NHPC Dam site is done. The surrounding land is grazing and forest.

*c. River Subansiri at Chauldhoaghat*

The sampling site is located near the NH Bridge at Chauldhua village in North Lakhimpur. Thakaraguri village is located on the opposite bank of River Sugansiri. Sampling site was selected in between Road Bridge and Rail Bridge Opp. to J. K. Hotel on National Highway. Arunachal Pradesh hills are located towards Rail Bridge. The backwater of the river is used for various purposes like washing, bathing etc.

*d. River Subansiri at Alichiga, Bordubi*

Alichiga is located 90 km downstream from Gerukamukh near Trinayan Mandir at Nutal, Tinali. Morolia village is located on the opposite bank of River Subansiri. The sampling site was selected before confluence of River Subansiri with River Brahmaputra. Lakhimpur town is about 20-25 km from this location. The sampling was carried out on the Subansirimukh bank towards ferry ghat and also at opposite bank towards Morolia village. The forest is covered on the other bank towards Jorhat. River Subansiri joins River Brahmaputra in Majulighat at a distance of about 4 km downstream from this location.

## *RIVER BORAK*

River Borak is one of the important River in Borak valley of Assam state. River Borak comes from Manipur and passes through Silchar, Kathakal, Badarpur, Karimganj and then enters the Bangladesh territory.

1. River Borak at Fuler Tal, Jiribam

Through Fuler Tal sampling location river enters the Assam-Manipur border. The transport activity for crossing border is through ferry ghat services. The entire area is covered mainly by Tea gardens in the catchment. The other bank of river is towards Silchar, Sonbari and Manipur. Tea gardens start from Assam border.

2. River Borak at Dilkhush Tea Estate

This is the opposite bank of River Borak at Fooler Tal. The water body comes from the Manipur Border. The sampling site is located at upstream of water intake point. Borak valley starts from Assam border. From Ratachera Assam border is about 10 km on NH-44 and Badarpur is located at 44 km.

*b. River Borak at Kathakal*

The sampling site on River Borak is located adjacent to NH-44 at the outskirts of Silchar township. The sampling site is towards Anandpur, Kathakal of Silchar town. Panchgram H.P.C. is also located on this bank at upstream. Gonirgram Siripur Part-I is located on the opposite bank. The surrounding area is urban, Drain from Chachapra from Tukargram joins at upstream of this sampling location. Sampling location is in between Badarpur and Silchar. Chorangi Bazar is located on the opposite bank.

*c. River Borak at Badarpurghat, Badarpur*

This monitoring station was chosen on Borak river in the Borak Valley to assess the effect of effluent discharged in it from the Cachar Paper Mills at Panchgram in Cachar district. The sampling site on the River Borak is located after the confluence of HPC Panchgram effluents at Badarpur ghat. The sampling site is between the Old Railway Bridge and Road

Bridge. The entire stretch is subjected to construction activities of the New Railway Bridge. The water intake of railway is located near the sampling site. Panchgram HPC effluents join before Gamoh Bridge on River Borak. Katighra is on the opposite bank of River. River Dhansiri also joins River Borak at this point.

*d. River Borak Downstream at Kalibarighat, Karimganj*

The sampling site is at the border area of Assam and Bangladesh. The sampling site on River Borak is located between Steamerghat and Kalibarighat near Kalibari town in Karimganj. Charbazar is located at upstream. Bamboo boats float on the bank of River Borak to be used for various human activities. The BSF camp is located at upstream and Jakhiganj of Bangladesh is located towards opposite bank.

*BRAHMAPUTRA BASIN*

The Brahmaputra Basin extends over an area of nearly 5,80,000 $km^2$ and traverses a distance of about 2900 km through Tibet (China), India and Bangladesh. In India, the basin lies in the states of Arunachal Pradesh, Assam, Nagaland, Meghalaya and North Bengal. The Brahmaputra Basin is bounded on the north by the Himalayas, on the east by the Patkai range of hills running along the Assam-Myanmar Border, on the south by the Assam range of hills and on the west by the Himalayas. The ridge separates it from the Ganga Basin. The Basin has a maximum east-west length of about 1,540 km and a maximum north-south width of about 682 km along $93^0$ east longitude.

The River rises in the great glacier in the northern – most chain of the Himalayas in the Kailash range at an elevation of about 5,510 m at a latitude of 30’-31’ N, longitude of 82’-10’E just south of the lake called Konggyu Tsho. It enters India across the Sadiya frontiers tract, west of Sadiya town into the Assam valley. Here it is joined by two more tributaries viz. the Dibang or Siang and the Lohit, from here onwards the River is known as the Brahmaputra. The River then descends down into the Assam valley from east to west for a distance of about 720 km with its channels meandering from side to side and forming several islands, one of these islands, Majuli covers an area of 1,250 $km^2$. During its course the River receives many more tributaries both from the north and the south while some of them are trans-Himalayan Rivers with considerable discharge.

The Brahmaputra has the highest discharge of all the Rivers, because of heavy annual average rainfall in the catchment area. The River has eight significant tributaries in India; three from the north are the Manas, the Kameng (or the Jia Bhoreili) and the Subansiri and three from the east are the Dibang or Siang, the Lohit and the Buri Dihing and two from the north west are the Tista and the Jaldhaka.

*a. River Brahmaputra at Saikowaghat, Tinsukia*

River Brahmaputra started from the eastern end of Assam, Tinsukia and Dibrugarh Districts. These Districts are having maximum number of small, medium and a few large-scale industries like Digboi Refinery, Oil and Namrup Fertilizers alongwith the coal mining activities by north Eastern Coal Fields at Margherita and Ledo etc. At Saikhowaghat, Tinsukia the River Dibang, Dihing, Kundil, Lohit from Arunachal Pradesh and Dhola, join together to River Brahmaputra. The sampling site is erosion prone and a ferry ghat is located near the sampling station.

*b. River Brahmaputra at Nagagholli, Maizan, Dibrugarh*

Maijan is situated at the upstream of major townships of upper Assam. The sampling site is located in between Dibrugarh and Tea gardens. Digboi nullah carries the confluence with Dihing River, which is a major tributary to the Brahmaputra.

*c. River Brahmaputra at Disangmukh, Sibsagar*

The major activity that has direct bearing on the environment is the drilling of crude oil in Sibsagar district by ONGC Ltd. The ONGC Ltd has four major Oil fields at Gelaki, Lakwa, Demalgaon and Rudrasagar, which are continuously kept under vigilance by PCBA (Board). The sampling site is situated at about 16 km from the Sibsagar township.

*d. River Brahmaputra at Nimatighat, Jorhat*

The sampling site on River Brahmaputra is located at Nimatighat of Jorhat town. Majuli is located on the opposite bank of River at Lakhimpur. Kakilamukh Bird Sanctuary is located at this point. Wild elephants are also found in the sanctuary.

*e. River Brahmaputra at Dhanbari Camp, Golaghat*

At this location a major tributary River Dhansiri joins on the south bank of River Brahmaputra. River Dhansiri mostly cover the District of Golaghat and supposed to carry the wastewater from Numaligarh Refinery and contribute water quality to River Brahmaputra. Kaziranga ranges are located on the bank of River Brahmaputra.

*f. River Brahmaputra at Bhomuraguri, Silighat*

Bhomuraguri is located in between Silighat and Nagaon in Sonitpur District. The sampling location on River Brahmaputra is situated at a distance of 6 km from Tejpur town on NH-37A, which joins NH-37 at

Kaliabar to NH-52 at Mission Chariali, crossing the River after Brahmaputra Road Bridge. Before construction of the Road Bridge on River, it was a ferry ghat with human settlement on the bank. The ferry and motor boats were used to transport people from one place to other through River. Ari fishes (*Mystus* *Singhala*) are collected from River Brahmaputra and sold here. The forest department of Assam also maintained the Teak forest. River Buridihing, Disang, Dikrong, Jhanji, Subansiri, Dhansiri and other tributaries join River Brahmaputra at upstream of this location. Further, ahead River goes downstream to Bangladesh. Tejpur is located on the opposite bank of sampling site.

*g. River Brahmaputra at Saraighat, Guwahati*

Saraighat Bridge connects both the north & south bank of River Brahmaputra near Sadilapur at Guwahati. The sampling site is located at Pandughat before the Road Bridge. The Refinery effluents are discharged at upstream of this location. The Refinery is located at Noonmati. This is the downstream of Central Guwahati.

*h. River Brahmaputra at Joghigopa*

Situated at the downstream of Assam, Jogighopa is about 20 km from Bongaigaon, Industrial Township of Assam. Golpara is the nearest town to this location. Joghigopa is situated across the Panchratna Bridge also known as Naranarayan Setu on River Brahmaputra on NH-37. This town is located at a distance of 168 km from Guwahati. The sampling site is located near water intake point of Jogighopa Paper Mill in District Bongaigaon. Central Govt.'s Archaeological Department has developed historic site on the hill side. The entire catchment of River Brahmaputra at this location is used for coal storage, transport from Garo Hills of Meghalaya state. 2.8 km long rail cum Road Bridge is also present parallel to NH-37. Bamboo boats are used for various human activities on the bank. Pine tree shrubs have been planted on the bank. Beetle nut and Palm trees are common at this place. A big wetland has been formed from the flood water of Brahmaputra, which extends parallel to NH-37. After Guwahati, a number of tributaries like Manas, Puthimari, Pagladia, and Beki etc. join the Brahmaputra before Jogighopa.

*i. River Brahmaputra at Dhubri*

This is situated further downstream of Assam. Dhubri is the last monitoring station on River Brahmaputra before entering the territory of Bangladesh. After crossing the Dhubri District, the River takes its way to the Bangladesh. A match factory existed earlier at this location. Bongaigaon is located on the opposite bank of River.

*j.* *River Jia-Barali at Bukagaon*

River Jia-Barali before entering the Assam border, known as River Kameng in Arunachal Pradesh. Sampling locations on River Jia-Barali at Bukagaon is about 345 km from Jonai and 16 km from Jamuguri of Balipara Division on NH-52. The sampling site is located on River Jia-Barali near Road Bridge of NH-52. Department of Irrigation is located on the opposite bank at Towbhanga village. The sampling site is in between Rail Bridge and Road Bridge on River Jia-Barali. River Jia-Barali originates from the hills of Arunachal Pradesh and joins to River Brahmaputra. Fishing competition is held every year among N-E-States for maximum fish catch. The maximum weight reported for fish catch is 17 kg.

*RIVER MALIDOR, NEW MALIDOR, JALALPUR*

River Malidor passes through Meghalaya State and Karbi Anglong Tea Estate of Assam at Assam-Meghalaya border. River goes downstream to Bangladesh. The sampling location is situated near New Malidor, Jalalpur at Jaintia Hill Border Road. Sonapur is 48 km and Shillong is 145 km from this location. The sampling site on River Malidor was selected on NH-44 near Shiv Temple. Kalain is at 18 km from this location. Beetle nut plantation is common vegetation. Badarpur is 44 km and Umkiang is located at 3 km distance. Tea cultivation is done on hills near Kalain. White Rhododendrons are planted all along the forest. Borak valley starts from the Assam border at this location.

*RIVER RANGANADI AT PAHUMARA, LAKHIMPUR*

River Ranganadi is an important tributary of River Subansiri. Ranganadi originates from Arunachal Pradesh and joins River Subansiri at Pabori Reserve Forest, about 10-20 km from sampling site. Hydro-electric power generation is the major activity of Ranganadi Hydel Project of NEPCO Kameng in Arunachal Pradesh. The sampling site on Ranganadi is located near Road Bridge of NH-52, and 6 km from North Lakhimpur at Pahumara village. Bamundoloni village is situated on the opposite bank of River. Railway Bridge is parallel to Road Bridge on River Ranganadi. Egrets are observed quite often at this location.

*RIVER BOGINADI AT MILANPUR, LAKHIMPUR*

Boginadi comes from hills of Arunachal Pradesh and joins to River Subansiri at downstream at a distance of 3-4 km at Ghaggerghat. The sampling site is located at 16 km from Lakhimpur district on a bypass from NH-52 near Namghar. The opposite bank of River Boginadi is inhabited by Lalpari village. Ratanpur nullah from Hills join River Boginadi about 300-500 mtrs upstream from sampling site.

*RIVER DIKRONG AT BANDARDUA*

River Dikrong is a tributary of River Brahmaputra. River Dikrong arises from Arunachal Pradesh and joins River Brahmaputra at Majuli in Assam. The River Dikrong passes through border of Bandardua in Assam and Arunachal Pradesh. Itanagar is 25 km from NH-52 crossing. The sampling site on River Dikrong was selected at Harmutty Tea Estate near Higher Secondary School, Parbati Nagar, Bandardua. Harmutty Tea Estate is located towards the opposite bank of River Dikrong.

## 2.4 BIO-MONITORING OF PERENNIAL RIVERS IN ASSAM STATE

The bio-assessment of Perennial Rivers in Assam State was undertaken using Biological Water Quality Criteria (BWQC) using Saprobic Score and Diversity Score of water quality (Table 6).

**Table 6: Bio-monitoring of Perennial Rivers in Assam State**

| S. No. | Rivers/ Sampling Period | Location of Stretch | Temperature $^0$C | | Dissolved oxygen mg/l | pH | Saprobic Score | Diversity Score | Biological Water Quality Class | Biological Water Quality |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Air | Water | | | | | | |
| 1. | River Buridihing | Bed Camp at Miao in Arunachal Pradesh | 32.0 | 20.0 | 7.9 | 7.7 | 8.2 | 0.5 | A | Clean |
| | | | 20.0 | 17.0 | 9.3 | 7.5-7.8 | 9.5 | 0.5 | A | |
| | | Dihing, Ferryghat at Margherita | 24.0 | 23.0 | 6.3 | 6.5 | 5.3 | 0.37 | C | Moderate Pollution |
| | April, 2003 | | 24.0 | 23.0 | 6.9 | 6-6.5 | 4.8 | 0.42 | C | |
| | | Gammon, Dullang at Khowang, NH-37 | 23.0 | 21.0 | 5.9 | 6.7 | 5.3 | 0.48 | C | Moderate Pollution |
| | October, 2004 | | 24.0 | 22.0 | 6.7 | 6-7 | 5.2 | 0.40 | C | |
| | | Dihingmukh at Dibrugarh | 22.0 | 22.0 | 6.9 | 6.0 | 5.8 | 0.43 | C | Moderate Pollution |
| | | | 22.0 | 20.0 | 6.5 | 6-7 | 5.6 | 0.40 | C | |
| 2. | River Disang | Dillighat, Assam-Arunachal Pradesh border | 26.0 19.0 | 21.0 | 7.6 | 6.8 | 7.3 | 0.5 | A | Clean |
| | | | | 16.0 | 8.6 | 7-8 | 8.7 | 0.5 | A | |
| | | Lalpagari ghat at Namrup Industrial township | 22.0 | 18.0 | 6.6 | 6.0 | 5.0 | 0.44 | C | Moderate Pollution |
| | May, 2003 | | 22.0 | 18.0 | 6.0 | 7-7.5 | 5.0 | 0.29 | D | Heavy Pollution |
| | November, 2004 | Rajabari,Sibsagar | 30.0 | 26.0 | 6.0 | 6.8 | 4.8 | 0.41 | C | Moderate Pollution |
| | | | 22.0 | 19.0 | 7.1 | 6-7 | 6.0 | 0.45 | C | |
| | | Sepaigaon, Disangmukh Sibsagar | 30.0 | 25.0 | 5.8 | 6.4 | 5.7 | 0.39 | C | Moderate Pollution |
| | | | 22.0 | 20.0 | 6.8 | 6-7 | 5.3 | 0.44 | C | |
| 3. | River Jhanji | Amguri, Tea Estate, Rajabari, Assam-Nagaland Border | 31.0 | 24.0 | 6.2 | 6.8 | 6.2 | 0.51 | B | Slight pollution |
| | | | 20.0 | 18.0 | 7.4 | 7-7.5 | 6.6 | 0.53 | B | |
| | May, 2003 | NH-Crossing, Jhanji at Sibsagar | 30.0 | 26.0 | 6.7 | 6.5 | 5.7 | 0.39 | C | Moderate Pollution |
| | | | 23.0 | 21.0 | 6.7 | 6-7 | 5.3 | 0.42 | C | |
| | November, 2004 | Jhanjimukh, Kumargaon at Jorhat near Teok | 30.0 | 24.0 | 6.0 | 6.5 | 5.7 | 0.43 | C | Moderate Pollution |
| | | | 22.0 | 20.0 | 6.7 | 6-7 | 5.2 | 0.30 | C | |
| 4. | River Dhansiri | Kesharidubi, Tengani Nambar, Assam-Nagaland border | 26.0 | 22.0 | 5.9 | 7.0 | 6.5 | 0.54 | B | Slight pollution |
| | | | 20.0 | 17.0 | 7.4 | 7-8 | 6.5 | 0.55 | B | |

| S. No. | Rivers/ Sampling Period | Location of Stretch | Temperature $^0C$ | | Dissolved oxygen mg/l | pH | Saprobic Score | Diversity Score | Biological Water Quality Class | Biological Water Quality |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Air | Water | | | | | | |
| | May, 2003 | NRL Jetty at NH-Crossing, Numaligarh | 30.0 | 27.0 | 6.8 | 6.4 | 5.7 | 0.3 | C | Moderate Pollution |
| | | | 22.0 | 20.0 | 6.9 | 6-7 | 5.2 | 0.45 | C | |
| | November, 2004 | Dhansirimukh, Golaghat Nagaon district border | 29.0 | 26.0 | 6.9 | 6.3 | 5.2 | 0.42 | C | Moderate Pollution |
| | | | 20.0 | 17.0 | 7.0 | 7-7.5 | 4.7 | 0.35 | C | |
| 5. | Ellenga Beel System Pond | Belguri, Jagi Road | 32.0 | 29.0 | 1.4 | 7.9 | 5.0 | 0.31 | D | Heavy pollution |
| | May, 2003 | | 23.0 | 21.0 | 0.8 | 7-8 | 3.5 | 0.36 | C | Moderate Pollution |
| | December, 2004 | Jagi road, other side of Bridge, Morigaon | 33.0 | 29.0 | 0.6 | 8.0 | 2.7 | 0.37 | D | Heavy pollution |
| | | | 23.0 | 20.0 | 0.2 | 8.9 | 2.4 | 0.37 | D | |
| 6. | River Subansiri | Gerukamukh, Subansiri lower H.E. Project, North Lakhimpur District | 24.0 | 16.0 | 7.5 | 7.7 | 7.0 | 0.43 | A | Clean |
| | | Chaowlohoa ghat North Lakhimpur | 27.0 | 17.0 | 7.1 | 7.3 | 6.7 | 0.5 | B | Slight pollution |
| | May, 2003 | Alichiga, Bordubi | 29.0 | 22.0 | 6.3 | 7.0 | 5.0 | 0.33 | C | Moderate Pollution |
| 7. | River Borak | Fuler Tal, Jirbam, Assam-Manipur Border | 30.0 | 28.0 | 6.3 | 7.2 | 6.1 | 0.5 | B | Slight pollution |
| | May, 2003 | Katakhal, Silchar | 29.0 | 27.0 | 6.0 | 6.8 | 5.8 | 0.5 | C | Moderate Pollution |
| | | Badarpurghat, Badarpur | 32.0 | 29.0 | 6.1 | 5.7 | 5.2 | 0.43 | C | Moderate Pollution |
| | | Kalibarighat, Karimganj, Assam-Bangladesh border | 31.0 | 28.0 | 6.4 | 5.9 | 5.8 | 0.47 | C | Moderate Pollution |
| 8. | River Brahmaputra | Saikhowaghat, Tinsukia | 26.0 | 24.0 | 6.9 | 6.7 | 7.2 | 0.5 | A | Clean |
| | | | 19.0 | 17.0 | 8.2 | 7-7.5 | 7.8 | 0.5 | A | |
| | | Nagagholli, Maizan, Dibrugarh | 24.0 | 19.0 | 7.6 | 7.0 | 6.0 | 0.5 | B | Slight pollution |
| | | | 20.0 | 18.0 | 7.8 | 7.0 | 5.7 | 0.45 | C | |
| | | Disangmukh, Sibsagar | 30.0 | 24.0 | 6.7 | 6.6 | 5.6 | 0.5 | C | Moderate Pollution |
| | November, 2004 | | 23.0 | 20.0 | 7.9 | 6-7 | 6.0 | 0.5 | C | |
| | | Nimatighat, Jorhat | 28.0 | 20.0 | 7.4 | 7.6 | 5.3 | 0.39 | C | Moderate Pollution |
| | | | 22.0 | 19.0 | 7.5 | 7.0 | 5.7 | 0.50 | C | |
| | | Dhanbari Camp, Golaghat | 30.0 | 26.0 | 6.3 | 6.2 | 5.7 | 0.36 | C | Moderate Pollution |
| | | | 21.0 | 18.0 | 7.9 | 7-8 | 5.8 | 0.5 | C | |
| | December, 2004 | Bhomuraguri, Silighat | 28.0 | 28.0 | 6.6 | 7.2 | 5.7 | 0.44 | C | Moderate Pollution |
| | | | 22.0 | 20.0 | 7.8 | 6-7 | 6.0 | 0.56 | C | |
| | | Saraighat, Guwahati | 29.0 | 27.0 | 7.5 | 7.8 | 5.2 | 0.46 | C | Moderate Pollution |
| | | Jogighopa near Panchratna Bridge | 32.0 | 30.0 | 7.7 | 7.9 | 5.4 | 0.44 | C | Moderate Pollution |
| | April-May, 2003 | | 22.0 | 20.0 | 7.8 | 7.0 | 5.0 | 0.45 | C | |
| | | Dhubri | 31.0 | 27.0 | 6.7 | 6.9 | 5.6 | 0.35 | C | Moderate Pollution |
| | | | 22.0 | 20.0 | 7.7 | 6-7 | 6.2 | 0.50 | B | |
| 9. | River Brahmaputra | Pandu ghat, Sadilapur near Saraighat Bridge | 20.0 | 23.0 | 6.9 | 7.0 | 5.0 | 0.56 | C | Moderate Pollution |
| | November, 2003<br>December, 2004 | | 22.0 | 20.0 | 7.4 | 7.0 | 5.7 | 0.46 | C | |
| 10. | River Borak | Badarpur, Badarpurghat | 29.0 | 25.0 | 6.7 | 6-7 | 6.16 | 0.43 | C | Moderate Pollution |
| | | | 23.0 | 20.0 | 6.9 | 6-7 | 5.7 | 0.47 | C | |
| | | Kalighat, Karimganj | 26.5 | 22.5 | 6.9 | 6-7 | 5.3 | 0.45 | C | Moderate Pollution |
| | | | 22.0 | 20.0 | 7.0 | 6-7 | 5.8 | 0.47 | C | |

| S. No. | Rivers/ Sampling Period | Location of Stretch | Temperature $^0C$ | | Dissolved oxygen mg/l | pH | Saprobic Score | Diversity Score | Biological Water Quality Class | Biological Water Quality |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Air | Water | | | | | | |
| | November, 2003<br>November, 2004 | Katakhal on NH-44 | 26.0<br>23.0 | 23.5<br>21.0 | 7.4<br>7.6 | 6-7<br>6-7 | 5.7<br>5.7 | 0.61<br>0.58 | C<br>C | Moderate Pollution |
| | | Dilkhush Tea Estate opposite to Fuler Tal | 25.6 | 20.5 | 7.3 | 6-7 | 5.0 | 0.33 | C | Moderate Pollution |
| 11. | River Malidor<br>November, 2003<br>November, 2004 | New Malidor, Jalalpur, Assam-Meghalaya Border | 27.0<br>21.0 | 23.0<br>19.0 | 8.5<br>8.4 | 7.0<br>7.0 | 7.8<br>9.2 | 0.26<br>0.32 | A<br>A | Clean |
| 12. | River Borak Upstream<br>November, 2003<br>November, 2004 | Fuler Tal | 26.5<br>23.0 | 24.0<br>20.0 | 7.0<br>7.3 | 6-7<br>6-7 | 5.0<br>5.2 | 0.31<br>0.33 | C<br>C | Moderate Pollution |
| 13. | River Jia-Bharali | Bukagaon on NH-52 | 24.0 | 23.0 | 6.7 | 6-6.5 | 4.8 | 0.7 | C | Moderate Pollution |
| 14. | River Subansiri upstream<br>November, 2003<br>December, 2004 | Gerukamukh, Subansiri lower H.E. Project | 28.0<br>19.0 | 19.0<br>17.0 | 8.8<br>8.5 | 7-7.5<br>7-8 | 8.1<br>8.2 | 0.5<br>0.5 | A<br>A | Clean |
| | | Dhulumukh, Arunachal Pradesh border | 26.5 | 16.5 | 8.7 | 7-7.5 | 9.3 | 0.5 | A | Clean |
| | | Chauldhuaghat (Pub) north Lakhimpur | 25.5<br>22.0 | 21.0<br>20.0 | 8.2<br>7.9 | 6-7<br>6-7 | 9.0<br>8.7 | 0.57<br>0.5 | A<br>A | Clean |
| 15. | River Subansiri Downstream | Alichiga, 90 km from Gerukamukh | 24.0<br>22.0 | 18.5<br>19.0 | 7.4<br>7.9 | 6-7<br>6-7 | 5.3<br>5.5 | 0.33<br>0.37 | C<br>C | Moderate Pollution |
| 16. | River Ranganadi<br>November, 2003 | Pahumara, Lakhimpur | 31.0 | 25.0 | 7.1 | 6.0 | 4.0 | 0.32 | D | Heavy Pollution |
| 17. | River Boginadi | Boginadi, Milanpur, Lakhimpur District | 28.5 | 29.0 | 6-9 | 6.0 | 6.16 | 0.52 | B | Slight pollution |
| 18. | River Dikrong<br>November, 2003 | Harmutty Tea Estate on NH-52, near Higher Secondary School, Bandardua | 22.5 | 19.5 | 7.3 | 7-7.5 | 6.8 | 0.6 | B | Slight pollution |
| 19. | River Brahmaputra | Bhomuraguri Sonitpur District | 27.0 | 21.5 | 7.6 | 6-7 | 6.0 | 0.2 | C | Moderate Pollution |
| | | Jogighopa on NH-37 Panchratna Bridge | 27.0 | 26.0 | 7.6 | 7.0 | 5.1 | 0.48 | C | Moderate Pollution |
| 20. | River Lubha<br>November, 2004 | Near Lubha Bridge Sonapur, Meghalaya | 22.0 | 20.0 | 8.6 | 7.0 | 10.0 | 0.4 | A | Clean |

## Table 7: Clean Water (Class `A’) Stretches of Rivers in Assam State (2003)

| S. No. | Rivers/Water Bodies | District/Town/ Village | Location of stretch | Taxa/Families of benthic macro-invertebrates available from Rivers |
|---|---|---|---|---|
| 1. | River Buridihing<br>April & December, 2003 | Miao (Arunachal Pradesh) | Bed Camp | *EPHEMEROPTERA/Heptageniidae, Ephemeridae, Pothaminthidae, Caenidae, Baetidae, Leptophlebiidae* |

<table>
<tr><th>S. No.</th><th>Rivers/Water Bodies</th><th>District/Town/ Village</th><th>Location of stretch</th><th>Taxa/Families of benthic macro-invertebrates available from Rivers</th></tr>
<tr><td>2.</td><td>River Disang<br><br>May & December, 2003</td><td>Assam-Arunachal Pradesh Border</td><td>Dillighat</td><td rowspan="7">PLECOPTERA/Perlidae<br><br>TRICHOPTERA/Goeridae, Rhyacophilidae<br><br>ODONATA/Lestidae, Gomphidae,Corduliidae<br><br>MOLLUSCA/Viviparidae, Thiaridae, Bithynidae<br><br>COLEOPTERA/Hygrobidae, Noteridae<br><br>CRUSTACEA/Atydae<br><br>HEMIPTERA/Nepidae<br><br>PLANARIA/Planariidae</td></tr>
<tr><td rowspan="3">3.</td><td rowspan="3">River Subansiri<br><br>May & November, 2003</td><td>Gerukamukh, North Lakhimpur</td><td>Subansiri Lower H.E. Project</td></tr>
<tr><td>Dhulumukh Arunachal Pradesh Border</td><td>Opposite Bank of River at Gerukamukh</td></tr>
<tr><td>North Lakhimpur</td><td>Chauldhuaghat</td></tr>
<tr><td>4.</td><td>River Brahmputra<br><br>May & December, 2003</td><td>Tinsukia</td><td>Saikowaghat</td></tr>
<tr><td>5.</td><td>River Malidor<br><br>November, 2003</td><td>New Malidor<br><br>Jalalpur, Assam-Meghalaya Border</td><td>Shiv temple near NH-44</td></tr>
</table>

## Table 7a: Clean Water (Class `A') Stretches of Rivers in Assam during 2004

| S. No. | Rivers/Water Bodies | District/Town/ Village | Location of stretch | Taxa/Families of benthic macro-invertebrates available from Rivers |
|---|---|---|---|---|
| 1. | River Buridihing | Miao (Arunachal Pradesh) | Bed Camp | *EPHEMEROPTERA/Heptageniidae, Ephemeridae, Caenidae*<br>*PLECOPTERA/Perlidae*<br>*TRICHOPTERA/Goeridae*<br>*ODONATA/ Gomphidae, Lestidae*<br>*MOLLUSCA/ Thiaridae*<br>*CRUSTACEA/Atydae* |
| 2. | River Disang | Assam-Arunachal Pradesh Border | Dillighat | |
| 3. | River Subansiri | Gerukamukh, North Lakhimpur | Subansiri Lower H.E. Project | |
| | | Dhulumukh Arunachal Pradesh Border | Opposite Bank of River at Gerukamukh | |
| | | North Lakhimpur | Chauldhuaghat | |
| 4. | River Lubha | Near Lubha Bridge | Sonapur, Meghalaya | |
| 5. | River Malidor | Jalalpur | Assam Meghalaya Border | |

## Table 7b: Slightly Polluted Water (Class `B') Stretches of Rivers in Assam State (2004)

| S. No. | Rivers/Water Bodies | District/Town/ Village | Location of stretch | Taxa/Families of benthic macro-invertebrates available from Rivers |
|---|---|---|---|---|
| 1. | River Jhanji<br>November, 2004 | Rajabari, Assam – Nagaland Border | Amguri Tea Estate | *ODONATA/ Lestidae, Gomphidae*<br>*MOLLUSCA/ Thiaridae*<br>*CRUSTACEA/Atydae, Gammaridae*<br>*HEMIPTERA/Nepidae* |
| 2. | River Dhansiri<br>November, 2004 | Kesharidubi, Tengani, Nambar | Assam – Nagaland Border | |
| 3. | River Brahmaputra<br>December, 2004 | Balasur | Dhubri | |

## Table 7c: Moderately Polluted Water (Class `C') Stretches of Rivers in Assam State (2004)

| S. No. | Rivers/Water Bodies | District/Town/ Village | Location of stretch | Taxa/Families of benthic macro-invertebrates available from Rivers |
|---|---|---|---|---|
| 1. | River Buridihing<br>October, 2004 | Dihing, Margherita | Ferry ghat | *TRICHOPTERA/Hydropsychidae*<br>*ODONATA/ Lestidae, Gomphidae, Libellulidae*<br>*CRUSTACEA/Atydae, Gammaridae*<br>*MOLLUSCA/Thiaridae, Sphaeridae, Viviparidae, Unionidae, Planorbidae, Lymnaeidae,*<br>*HEMIPTERA/Nepidae*<br>*COLEOPTERA/ Gyrinidae, Hydrophilidae*<br>*OLIGOCHAETA/Oligochaetes*<br>*DIPTERA/Chironomidae* |
| | | Gommon | Dullang at Khowang NH-37 | |
| | | Dibrugarh | Dihingmukh | |
| 2. | River Disang<br>November, 2004 | Rajabari, | Sibsagar | |
| | | Sipaigaon, Disangmukh | Sibsagar | |
| 3. | River Jhanji<br>November, 2004 | Jhanji | NH-Crossing at Sibsagar | |
| | | Jorhat, Jhanjhimukh | Kumargaon near Teok | |
| 4. | River Dhansiri<br>November, 2004 | Numaligarh | NRL Jetty at NH-Crossing | |
| | | Golaghat, Dhansirimukh Nagaon | Nagaon district border | |
| 5. | Ellenga Beel System Pond<br>December, 2004 | Belguri | Jagi Road | |
| 6. | River Brahmaputra November-December, 2004 | Dibrugarh | Nagagholli, Maizan | |
| | | Disangmukh | Sibsagar | |
| | | Jorhat | Nimatighat | |
| | | Golaghat | Dhanbari Camp | |
| | | Bhomuraguri | Silighat | |
| | | Guwahati | Saraighat | |
| | | Jogighopa | Near Panchratna Bridge | |
| | | Guwahati | Pandughat, Sadilapur near Saraighat Bridge | |
| 7. | River Borak<br>November, 2004 | Badarpur | Badarpur Ghat | |
| | | Karimganj | Kalighat | |
| | | Katakhal | On NH-44 | |
| | | Fuler Tal | Fuler Tal | |
| 8. | River Subansiri downstream | Alichiga | 80 km from Gerukamukh | |

## Table 7d: Highly Polluted Water (Class `D') Stretches of Rivers in Assam State (2004)

| S. No. | Rivers/Water Bodies | District/Town/ Village | Location of stretch | Taxa/Families of benthic macro-invertebrates available from Rivers |
|---|---|---|---|---|
| 1. | River Disang<br>November, 2004 | Namrup | Lalpagari Ghat at Namrup Industrial township | *CRUSTACEA/Atydae*<br>*ODONATA/ Gomphidae*<br>*MOLLUSCA/ Sphaeridae, Thiaridae*<br>*HIRUDINEA/Glossiphonidae, Hirudidae*<br>*DIPTERA/Chironomidae*<br>*OLIGOCHAETA/Oligochaetes* |
| 2. | Ellenga Beel System Pond<br>December, 2004 | Jagi road, Morigaon | Other side of Bridge | |

## Table 8: Slightly Polluted Water (Class `B') Stretches of Rivers in Assam State (2003)

| S. No. | Rivers/Water Bodies & Sampling period | District/Town/ Village | Location of stretch | Taxa/Families of benthic macro-invertebrates available from Rivers |
|---|---|---|---|---|
| 1. | River Jhanji<br>May & December, 2003 | Rajabari, Assam-Nagaland border | Amghri Tea Estate | *EPHEMEROPTERA/Leptophlebiidae*<br>*PLECOPTERA/Perlidae*<br>*TRICHOPTERA/Hydropsychidae*<br>*ODONATA/Lestidae, Gomphidae,Libellulidae, Corduliidae*<br>*MOLLUSCA/Viviparidae, Thiaridae, Bithynidae, Unionidae, Planorbidae*<br>*CRUSTACEA/Atydae, Gammaridae*<br>*HEMIPTERA/Nepidae*<br>*COLEOPTERA/Gyrinidae, Haliplidae, Hygrobidae*<br>*DIPTERA/Chironomidae* |
| 2. | River Dhansiri<br>May & December, 2003 | Assam-Nagaland Border | Kesharidubi, Tengani, Nambar | |
| 3. | River Brahmaputra<br>May & December, 2003 | Maizan, Dibrugarh | Nagagholli | |
| | | Dhubri | Dhubri | |
| 4. | River Subansiri<br>May, 2003 | North Lakhimpur | Chaowlohoaghat | |
| 5. | River Borak<br>May, 2003 | Jirbam, Assam-Nagaland Border | Fuler Tal | |
| 6. | River Boginadi<br>November, 2003 | Milanpur, Lakhimpur District | Boginadi Pul | |
| 7. | River Dikrong<br>November, 2003 | Bandardua, Harmutty Tea Estate | Parbati Nagar, Near Higher Secondary School, NH-52 | |
| 8. | River Disang<br>December, 2003 | Sepaigaon, Sibsagar | Desangmukh | |

## Table 9: Moderately Polluted Water (Class `C') Stretches of Rivers in Assam State (2003)

| S. No. | Rivers/Water Bodies | District/Town/ Village | Location of stretch | Taxa/Families of benthic macro-invertebrates available from Rivers |
|---|---|---|---|---|
| 1. | River Buridihing | Dihing, Margherita | Ferry ghat | *TRICHOPTERA/Hydropsychidae*<br>*ODONATA/Gomphidae, Lestidae, Libellulidae*<br>*MOLLUSCA/Thiaridae, Sphaeridae, Viviparidae, Planorbidae, Hydrobiidae, Ancylidae, Bithynidae, Lymnaeidae,*<br>*CRUSTACEA/Atydae, Gammaridae*<br>*HEMIPTERA/Nepidae, Belastomatidae*<br>*COLEOPTERA/Heliplidae, Gyrinidae, Hydrophilidae, Dytiscidae, Noteridae*<br>*HIRUDINEA/Glossiphonidae*<br>*OLIGOCHAETA/Oligochaetes*<br>*DIPTERA/Chironomidae* |
| | | Gomman, Dullang at Khowang | Near NH-37 Road Bridge | |
| | April & December, 2003 | Dibrugarh, Sibsagar | Near NH-Road Bridge, Maizan Tea Estate | |
| 2. | River Disang | Namrup Industrial Township | Lalpagari ghat | |
| | | Rajabari, Sibsagar | Near NH-37 Road Bridge | |
| | May & December, 2003 | Sipaigaon, Sibsagar | Disangmukh | |
| 3. | River Jhanji | Jhanji at Sibsagar | NH-Crossing | |
| | May & December, 2003 | Kumargaon at Jorhat | Jhanjimukh near Teok | |
| 4. | River Dhansiri | Golaghat / Numaligarh | NRL Jetty at NH-Crossing | |
| | May & December, 2003 | Golaghat-Nagaon District border | Dhansirimukh | |
| 5. | River Subansiri<br>May & November, 2003 | Bordubi, Lakhimpur | Alichiga | |
| 6. | River Borak<br>May, 2003 | Golaghat / Silchar | Katakhal | |
| | | Karimganj / Badarpur | Badarpurghat | |
| | | Karinganj, Assam-Bangladesh Border | Kalibarighat | |
| | | Kathakal | On NH-44 | |
| | | Dilkhush Tea Estate | Opposite to Fuler Tal | |
| | | Assam-Manipur border | Fuler Tal | |

| S. No. | Rivers/Water Bodies | District/Town/ Village | Location of stretch | Taxa/Families of benthic macro-invertebrates available from Rivers |
|---|---|---|---|---|
| 7. | River Brahmaputra | Sibsagar | Disangmukh | |
| | | Jorhat | Nimatighat | |
| | | Golaghat | Dhanbari camp | |
| | | Silighat | Bhomuraguri | |
| | | Guwahati | Saraighat | |
| | | Jogighopa | Near Panchratna Bridge | |
| | May, November & December, 2003 | Dhubri | Dhubri | |
| 8. | River Jia-Bharali<br>November, 2003 | Sonitpur | On NH-52 Road Bridge | |
| 9. | Ellenga Beel System Pond<br>December, 2003 | Nowgaon | Jagiroad | |

## Table 10: Highly Polluted Water (Class `D') Stretches of Rivers in Assam State (2003)

| S. No. | Rivers/Water Bodies | District/Town/ Village | Location of stretch | Taxa/Families of benthic macro-invertebrates available from Rivers |
|---|---|---|---|---|
| 1. | Ellenga Beel<br>May & December, 2003 | Morigaon / Jagiroad | Jagi Road | *EPHEMEROPTERA/Baetidae*<br>*CRUSTACEA/Atydae*<br>*MOLLUSCA/Viviparidae, Planorbidae, Sphoeridae, Thiaridae*<br>*COLEOPTERA/Haliplidae*<br>*HEMIPTERA/Pleidae*<br>*HIRUDINEA/Glossiphonidae, Hirudidae*<br>*DIPTERA/Chironomidae*<br>*OLIGOCHAETA/Oligochaetes* |
| | | | Jagiroad, other side of Jagiroad | |
| 2. | River Ranganadi<br>November, 2003 | Lakhimpur | Pahumara | |
| 3. | River Disang<br>December, 2003 | Namrup Industrial Township | Lalpagari ghat | |

### Table 11: Taxonomic Composition of Benthic Macro-Invertebrates collected from Rivers of Assam

| S. No. | Taxa | % Taxonomic composition of Benthic Macro-invertebrates in Biological Water Quality Class | | | | |
|---|---|---|---|---|---|---|
| | | Class `A' | Class `B' | Class `C' | Class `D' | Class `E' |
| 1. | Arthropoda | 80.0 | 73.68 | 58.33 | 41.66 | 0.0 |
| | (i) Insecta | 93.75 | 63.45 | 85.71 | 33.33 | 0.0 |
| | (ii) Crustacea | 6.25 | 14.28 | 14.28 | 20.0 | 0.0 |
| 2. | Mollusca | 15.0 | 26.31 | 33.33 | 33.33 | 0.0 |
| 3. | Platyhelminthes | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4. | Annelida | 0.0 | 0.0 | 8.33 | 25.0 | 0.0 |

### Table 12: Development of Biological Water Quality Criteria for Rivers of Assam State

| S. No. | Taxonomic Group | Range of Saprobic score (1-10) | Range of Diversity Score (0-1) | Water quality characteristics | Water Quality Class | Indicator Colour |
|---|---|---|---|---|---|---|
| 1. | EPHEMEROPTERA, PLECOPTERA, TRICHOPTERA, ODONATA, MOLLUSCA, COLEOPTERA, CRUSTACEA, HEMIPTERA, PLANARIA | 7.0 - 9.3 | 0.26 - 0.57 | Clean | A | Blue |
| 2. | EPHEMEROPTERA, PLECOPTERA, TRICHOPTERA, ODONATA, MOLLUSCA, CRUSTACEA, HEMIPTERA, COLEOPTERA, DIPTERA | 6.0 - 6.8 | 0.5 - 0.6 | Slight pollution | B | Light Blue |
| 3. | TRICHOPTERA, ODONATA, MOLLUSCA, CRUSTACEA, HEMIPTERA, COLEOPTERA, HIRUDINEA, OLIGOCHAETA, DIPTERA | 3.5 - 6.16 | 0.2 - 0.7 | Moderate pollution | C | Green |
| 4. | EPHEMEROPTERA, CRUSTACEA, MOLLUSCA, COLEOPTERA, HEMIPTERA, HIRUDINEA, DIPTERA, OLIGOCHAETA | 2.2 - 5.0 | 0.3 - 0.37 | Heavy pollution | D | Orange |
| 5. | No benthic macro-invertebrates | 0.0 - 0.0 | 0.0 – 0.0 | Severe pollution | E | Red |

## 3.0 BIOLOGICAL WATER QUALITY ASSESSMENT OF PERENNIAL RIVERS IN ASSAM STATE

In Assam State, 46 numbers of river stretches have been assessed for bio-mapping of 14 rivers and tributaries. Out of 46 rivers stretches, 7 river stretches belonging to 5 major rivers namely, River Buridihing at Miaow, River Disang at Dillighat, River Subansiri at Gerukamukh, Dhulumukh, in North Lakhimpur, River Brahmaputra at Tinsukia and River Malidor at New Malidor were indicating the clean water quality (Class `A'). Nine river stretches of total 8 numbers of Rivers such as River Jhanji at Rajabari, River Dhansiri at Nambar, River Brahmaputra at Dibrugarh, River Subansiri at, River Borak at Fuler Tal, River Boginadi at Lakhimpur District, River Dikrong at Bandardua and River Disang at Desangmukh were slightly polluted (Class `B'). Moderate pollution in water quality of Class `C' was observed in 26 number of river stretches of 9 rivers and tributaries like River Buridihing, River Jhanji, River Dhansiri, River Subansiri, Borak River, River Brahmaputra, River Jia-Bharali and Ellenga Beel Pond System at various locations and different seasons (Table 9). Water quality of Ellenga Beel System Pond at Belguri and Morigaon in May and December was found polluted. Therefore, 4 river stretches of 3 number of water bodies including River Ranganadi and River Disang at Namrup Industrial Township were lying in Class `D' of highly polluted water quality. None of the water bodies showed severe pollution Class `E' of water quality.

River Brahmaputra from its origin to its downstream reaches exhibits different classes of water quality at nine locations (A to I) as shown in Fig. 1. River Brahmaputra water quality is clean only in its upstream stretches at Saikowaghat in Tinsukia. At downstream of this location River Brahmaputra gets slightly polluted at Maizan in Dibrugarh. Rest of the seven locations from downstream Dibrugarh, the water quality of River Brahmaputra remains moderately polluted in Class `C' of water quality. These locations are at Sibsagar, Jorhat, Golaghat, Silighat, Guwahati, Jogighopa and Dhubri. At Dhubri, the water quality of River Brahmaputra gets diluted by the confluence of several tributaries and thus regains its water quality from moderate to slightly polluted water quality class `B' specially during month of December, 2003.

The taxonomic composition of Benthic macro-invertebrates collected from clean water quality stretches (Class `A') of Rivers (Table 7) in Assam supported 20 number of families whereas slightly polluted (Class `B') river stretches were indicated by 19 numbers of families (Table 8). Maximum of 24 numbers of families showed moderate pollution (Class `C') of water quality (Table 9). Highly polluted (Class `D') water quality inhabited only 10 numbers of families (Table 10). 80% of Arthropods dominated the clean water quality stretches. Their population gradually reduced with the increase in pollution of water quality of Class `B, C & D. Molluscs and Annelids were maximum in highly polluted water of Class `D'. No benthic animals belonging to Class `E' were observed (Table 12).

A comparison of Bio-map (Fig. 1 & 2) of year 2003 & 2004 indicates no change in water quality at most of the locations on River Brahmaputra & its tributaries except for few locations. For example, the biological water quality of River Disang at Lalpagari Ghat at Namrup Industrial Township has changed, from Moderate Pollution (Class `C') in 2003 to Heavy Pollution (Class `D') in year 2004. Similarly, the biological water quality of River Brahmaputra at Nagagholli, Maizan in Dibrugarh was slightly polluted in year 2003 and degraded to Heavy Pollution (Class `D') in year 2004.

Water quality of River Brahmaputra at Nagagholli Maizan in Dibrugarh was slightly polluted (Class `B') in 2003 and shifted to Moderate Pollution (Class `C') in 2004. On the other hand, water quality of Ellenga Beel System Pond at Jagiroad, Belguri indicates improvement in year 2004 indicating Moderate Pollution and upgrading from Heavy Pollution during year 2003. Dhubri Station is the last sampling location on River Brahmaputra, which depicts the overall water quality of River Brahmaputra at downstream of Assam State. The biological water quality of River Brahmaputra improved to slight pollution (Class `D') in 2004 compared to Moderate Pollution (Class `C') in year 2003. Following table indicates the total number of families of benthic macro-invertebrates collected during year 2003 and 2004:

| **Biological Water Quality Class** | **Total Number of Families of Benthic Macro-Invertebrates** | |
|---|---|---|
| | **Year 2003** | **Year 2004** |
| A | 19 | 9 |
| B | 19 | 6 |
| C | 24 | 17 |
| D | 12 | 8 |

An actual water quality assessment relies on collection of mature colonization of benthic macro-invertebrates. Quite often the change in observations of water quality could be due to insufficient biological sampling.

## 4.0 COMPARISION OF BIOLOGICAL STATUS OF RIVERS IN MEGHALAYA AND ASSAM STATE

Although, Assam and Meghalaya are the sister states of North-Eastern India, their rivers differ from each other with respect to Taxonomical composition of biota (Table 13 & 14) and Biological Water Quality Criteria evolved from the saprobic score and diversity score of water quality (Table 15). Diptera and Megaloptera Taxonomic group of benthic macro-invertebrate families, were totally absent in clean water quality class `A' Rivers of Assam. Plecoptera group was absent in Class `B' water quality and Ephemeroptera and Megaloptera were absent in Class `C' Water Quality Rivers of Assam compared to taxonomic groups of water quality classes of Meghalaya State.

Taxonomic groups of Crustacea, Hemiptera and Ephemeroptera were the additional Taxa existed in the water quality class `D' of highly polluted rivers of Assam. Taxonomic groups of benthic macro-invertebrates of `E' Class water quality were not observed in Rivers of Assam and Meghalaya.

## Table 13: Comparison of Taxonomic composition of Benthic Macro-invertebrates in Assam & Meghalaya

| S. No. | Group/Taxa | % Taxonomic composition of Benthic Macro-invertebrates | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BWQC Class `A' | | BWQC Class `B' | | BWQC Class `C' | | BWQC Class `D' | | BWQC Class `E' | |
| | | Meghalaya | Assam | Meghalaya | Assam | Meghalaya | Assam | Meghalaya | Assam | Meghalaya | Assam |
| 1. | Arthropoda | 86.95 | 80.0 | 87.5 | 73.68 | 77.14 | 58.33 | 57.14 | 41.66 | 0.0 | 0.0 |
| | Insecta | 97.5 | 93.75 | 89.28 | 63.45 | 96.29 | 85.71 | 100.0 | 33.33 | 0.0 | 0.0 |
| | Crustacea | 2.5 | 6.25 | 7.15 | 14.28 | 3.7 | 14.28 | - | 20.0 | 0.0 | 0.0 |
| 2. | Mollusca | 10.86 | 15.0 | 9.37 | 26.31 | 11.428 | 33.33 | 14.28 | 33.33 | 0.0 | 0.0 |
| 3. | Platyhelminthes | 2.17 | 5.0 | 3.12 | 0.0 | - | 0.0 | - | 0.0 | 0.0 | 0.0 |
| 4. | Annelida | - | 0.0 | - | 0.0 | 11.42 | 8.33 | 28.57 | 25.0 | 0.0 | 0.0 |

## Table 14: Comparison of Biological Status of Rivers of Meghalaya and Assam

| S. No. | Taxonomic Group | | Range of Saprobic score | | Range of Diversity Score | | Water quality | Water Quality Class | Indicator Colour |
|---|---|---|---|---|---|---|---|---|---|
| | Meghalaya | Assam | Meghalaya | Assam | Meghalaya | Assam | | | |
| 1. | EPHEMEROPTERA<br>PLECOPTERA<br>TRICHOPTERA<br>ODONATA<br>MOLLUSCA<br>CRUSTACEA<br>HEMIPTERA<br>COLEOPTERA<br>DIPTERA<br>PLANARIA<br>MEGALOPTERA | EPHEMEROPTERA<br>PLECOPTERA<br>TRICHOPTERA<br>ODONATA<br>MOLLUSCA<br>CRUSTACEA<br>HEMIPTERA<br>COLEOPTERA<br>PLANARIA<br>-<br>- | 7.0-8.6 | 7.0-9.3 | 0.2-0.8 | 0.26-0.57 | Clean | A | Blue |
| 2. | EPHEMEROPTERA<br>PLECOPTERA<br>TRICHOPTERA<br>ODONATA<br>MOLLUSCA<br>CRUSTACEA<br>HEMIPTERA<br>COLEOPTERA<br>DIPTERA<br>PLANARIA | EPHEMEROPTERA<br>PLECOPTERA<br>TRICHOPTERA<br>ODONATA<br>MOLLUSCA<br>CRUSTACEA<br>HEMIPTERA<br>COLEOPTERA<br>DIPTERA<br>- | 6.0-6.7 | 6.0-6.8 | 0.47-0.72 | 0.5-0.6 | Slight pollution | B | Light Blue |
| 3. | EPHEMEROPTERA<br>TRICHOPTERA<br>ODONATA<br>MOLLUSCA<br>CRUSTACEA<br>HEMIPTERA<br>COLEOPTERA<br>DIPTERA<br>MEGALOPTERA<br>HIRUDINEA<br>OLIGOCHAETA | TRICHOPTERA<br>ODONATA<br>MOLLUSCA<br>CRUSTACEA<br>HEMIPTERA<br>COLEOPTERA<br>DIPTERA<br>HIRUDINEA<br>OLIGOCHAETA<br>-<br>- | 3.4-6.2 | 4.2-6.16 | 0.2-0.8 | 0.2-0.7 | Moderate pollution | C | Green |
| 4. | MOLLUSCA<br>DIPTERA<br>HIRUDINEA<br>COLEOPTERA<br>OLIGOCHAETA<br>-<br>-<br>- | MOLLUSCA<br>DIPTERA<br>HIRUDINEA<br>COLEOPTERA<br>OLIGOCHAETA<br>CRUSTACEA<br>HEMIPTERA<br>EPHEMEROPTERA | 2.6-6.0 | 2.2-5.0 | 0.2-0.3 | 0.3-0.37 | Heavy pollution | D | Orange |
| 5. | No benthic macro-invertebrates | | 0.0 | 0.0 | 0.0 | 0.0 | Severe pollution | E | Red |

# Sewage Pollution -February 2005

## Editorial

Sewage is wastewater generated from domestic activities including kitchen, bathroom, toilet & floor washing. It is basically an urban issue. In rural areas sewage is insignificant. Fast urbanization and increasing standards of living resulting in steep increase in generation of sewage in the country. Due to paucity of resources, the sewage is not properly collected & treated in most of the urban centers of India. Nearly 2/3rd of the pollution problem is due to discharge of untreated or partially treated sewage in our country. It is estimated that about 23,000 million litres of sewage is generated every day out of which treatment capacity exists only for about 6,000 million litres per day including the capacity created under the Ganga Action Plan, the Yamuna Action Plan and others under National River Action Plan. Due to inadequate collection system, the sewage is accumulated within urban areas forming cess pools promoting breeding of mosquitoes, percolating in the ground & polluting the groundwater, the only source of drinking in many urban areas, which may pose serious health hazard. It also disturbs river ecology as a whole to a large extent. There are some river stretches where aquatic life, except bacteria, is completely missing due to mixing of large quantities of untreated sewage. Despite several efforts for proper sewage management, it still is the most important source of pollution in every river of the country. All the river cleaning projects revolve around proper sewage management.

Conventionally sewage is collected through a vast network of sewerage system & transported to a centalized treatment plant, which is resource intensive. Instead of transporting it to long distance for centralized treatment, Central Pollution Control Board is promoting decentralized treatment at local level using technology based on natural processes.

Sewage, after proper treatment can be used in pisciculture, irrigation, forestry and horticulture. Its conventional treatment generates sludge, which acts as manure. The sludge can also be used for energy recovery. Some sewage treatment plants in the country are recovering this energy and utilizing it.

The sewage is generated by all of us, therefore, with little care we can somewhat reduce its amount. "We must save water because water is scarce and limited", all of us know it but saving water also reduced the quantity of sewage.

This issue of Parivesh deals with various aspects of sewage, including treatment options and utilization. I hope it will help common people in developing some awareness about sewage.

V. Rajagopalan

**(V. Rajagopalan)**
**CHAIRMAIN, CPCB**

## INTRODUCTION

India is rich in water resources, having a network of as many as 113 rivers (the figure does not include tributaries) and vast alluvial basins to hold plenty of groundwater. India is also blessed with snow-capped peaks in the Himalayan range, which can meet a variety of water requirements of the country. However, with the rapid increase in the population of the country and the need to meet the increasing demands of irrigation, domestic and industrial consumption, the available water resources in many parts of the country are getting depleted and the water quality has deteriorated. In India, water pollution comes from three main sources: domestic sewage, industrial effluents and run-off from agriculture.

*Urban environmental management is one of the most pressing issues as the urbanization trend continues globally. Among the challenges faced by urban planners is the need to ensure ongoing basic human services such as the provision of water and sanitation. The under-management of domestic wastewater in many southern urban areas presents a major challenge. The accumulation of human waste is constant and unmanaged wastewater directly contributes to the contamination of locally available freshwater supplies. Additionally, the cumulative results of unmanaged wastewater can have broad degenerative effects on both public and ecosystem health.*

The most significant environmental problem and threat to public health in both rural and urban India is inadequate access to clean drinking water and sanitation facilities. Almost all the surface water sources are contaminated to some extent by organic pollutants and bacterial contamination and make them unfit for human consumption unless disinfected. The diseases commonly caused by contaminated water are typhoid, cholera, gastroenteritis, bacterial dysentery, hepatitis, poliomycitis, amoebic dysentery etc.

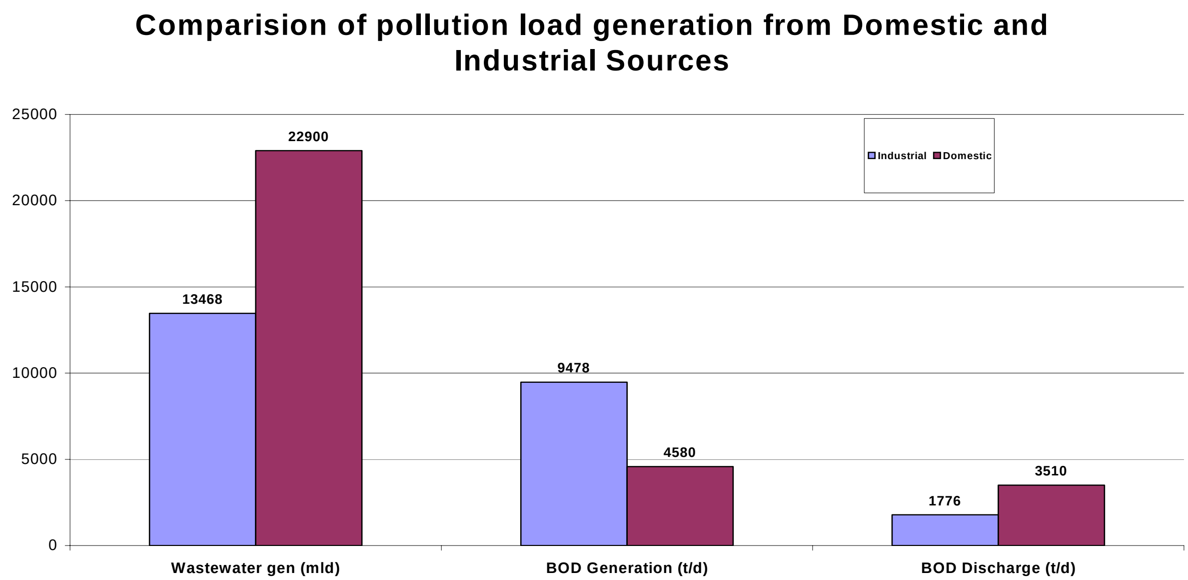
## WASTEWATER GENERATION & TREATMENT: DOMESTIC SEWAGE VS INDUSTRIAL EFFLUENT

It is estimated that 22,900 million litres per day (MLD) of domestic wastewater is generated from urban centres against 13,500 MLD industrial wastewater. The treatment capacity available for domestic wastewater is only for 5,900 MLD, against 8,000 MLD of industrial wastewater. Thus, there is a big gap in treatment of domestic wastewater. Govt. of India is assisting the local bodies to establish sewage treatment plants under the Ganga Action Plan and subsequently under the National River Action Plan. Since the task is massive, it may take long time to tackle the treatment of entire wastewater. It is estimated that the total cost for establishing treatment system for the entire domestic wastewater would be around Rs. 7,560 crores. Operation & maintenance cost would be in addition to this cost. Similarly, there is a gap in treatment of about 5,500 MLD of industrial wastewater, mainly generated from small-scale industries. Establishing effluent treatment systems in small-scale industries is a problem, since a large number

*Domestic human waste includes human excreta, urine and the associated sludge (collectively known as black water), and wastewater generated through bathing and kitchen (collectively known as grey water).*

*In 1950, the average daily output of human waste (i.e. excrement and urine) was estimated to be 3.2 million tonnes; in the year 2000, the estimated daily output was 8.5 million tonnes.*

of them are located in residential areas, where space is a constraint. Moreover, the small-scale industries are not having adequate resources to establish treatment systems. Such industries need to establish common effluent treatment plants (CETPs). A number of such facilities have been established across the country. It is expected that establishment of CETPs would reduce the pollution load in the aquatic resources of the country to a large extent.




## URBANISATION & WASTEWATER MANAGEMENT IN INDIA

The process of urbanisation in India since the beginning of last century reveals a steady increase in the size of its urban population, number of urban centres, and level of urbanisation since 1911 onwards and a rapid rise after 1951. From a modest base of 25.8 million persons in 1901, the number of urban dwellers has risen to 285 million, signalling a phenomenal eleven fold increase in urban population over the period 1901-2001.

The urban India has become a massive and perhaps a frightening reality as far as waste management is concerned. This country can no longer afford to allow urban areas constituting cities and towns of varying magnitude to take care of them; they need the full and undivided attention of our planners and decision makers for protection of environment, aquatic resources and ultimately for better management of health aspects.

The Central Pollution Control Board realised the gravity of water quality deterioration in water bodies and instituted studies on the wastewater management in India with changing urban pattern during last three decades and highlighted the need for urban wastewater management. The comparison of water supply, wastewater generation, collection and treatment during 1978-79, 1989-90 and 1994-95 indicates that the wastewater generation has increased from 7,007mld in 1978-79 to 16,622 mld in 1994-95 in class I cities (population one lakh or above). However, the treatment capacity has increased from 2755.94 mld in 1978-79 to 4037.20 mld in 1994-95, which was only 39% and 24% of the wastewater generated respectively.

**Decadal Trend of water supply and sanitation status in Class I Cities and Class II towns**

| Parameters | Class I cities | | | Class II Towns | | |
|---|---|---|---|---|---|---|
| | **1978-79** | **1989-90** | **1994-95** | **1978-79** | **1989-90** | **1994-95** |
| Number | 142 | 212 | 299 | 190 | 241 | 345 |
| Population (millions) | 60 | 102 | 128 | 12.8 | 20.7 | 23.6 |
| Water Supply (mld) | 8,638 | 15,191 | 20,607 | 1533 | 1622 | 1936 |
| Wastewater generated (mld) | 7,007 | 12,145 | 16,662 | 1226 | 1280 | 1650 |
| Wastewater treated (mld) | 2,756 (39%) | 2,485 (20.5%) | 4,037 (24%) | 67 (5.44%) | 27 (2.12%) | 62 (3.73%) |
| Wastewater untreated (mld) | 4,251 (61% | 9,660 (79.5%) | 12,625 (76%) | 1160 (94.56%) | 1252 (97.88%) | 1588 (96.27%) |

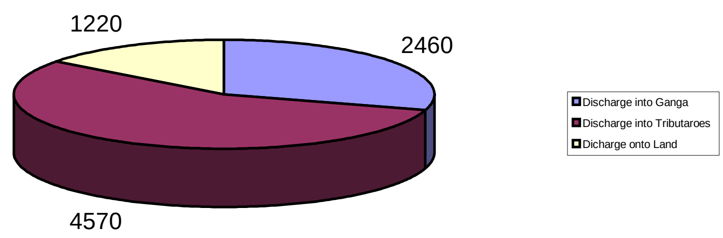
As per the updated status for the year 2003, out of 22,900 Mld of wastewater generated, only about 5,900 Mld (26%) is treated before letting out, the rest i.e., 17,100 Mld is disposed of untreated. Twenty-seven cities have only primary treatment facilities and forty-nine have primary and secondary treatment facilities. The level of treatment available in cities with existing treatment plant in terms of sewage being treated varies from 2.5% to 89% of the sewage generated. Treated or partly treated or untreated wastewater is disposed into natural drains joining rivers or lakes or used on land for irrigation/ fodder cultivation or disposed into the sea or a combination of them by the municipalities. The mode of disposal in 118 cities is indirectly but ultimately into the rivers/ lakes/ ponds/ creeks; in 63 cities to the agriculture land; in 41 cities directly into rivers and in 44 cities, it is discharged both into rivers and on agriculture land.

***Status of Sewage Treatment in the Ganga Basin***

The Ganga basin spreads over an area of 8,61,404 $Km^2$ covering the States of Uttaranchal, Uttar Pardesh, Haryana, Delhi, Madhya Pradesh, Rajasthan, Bihar, Jharkhand & West Bengal. There are 223 cities/towns (Municipalities/ Corporations) generating significant amount of sewage in the Ganga basin. These cities/towns generate about 8,250 MLD (million litre per day) of wastewater, out of which about 2,460 MLD is directly discharged into the Ganga river, about 4,570 MLD is discharged into its tributaries or sub- tributaries and about 1220 MLD is disposed on land or on low-lying areas.

Out of 8,250 MLD wastewater generated in the Ganga basin, the treatment facilities available for 3,500 MLD of wastewater. Out of 3,500 MLD treatment capacity, 882 MLD is created under the Ganga Action Plan, 720 MLD is created under the Yamuna Action Plan by NRCD/MoEF and about 1,927 MLD treatment capacity is created or under augmentation by the Govt. of Delhi for restoration of water quality in Yamuna river. The treatment facilities at 48 additional towns along the Ganga river and 23 towns on its tributaries/sub- tributaries are being created under GAP Phase-II and National River Action Plan. It is expected that after completion of these plans, an additional capacity of about 1,500 MLD will be created. However, still there will be a large gap between the wastewater generation and treatment capacity.

**Disposal of Sewage generated in Ganga Basin in million litres per day**




**Sewage Generation, Treatment and Disposal in the Ganga Basin**

***Sewage Generation***

| | |
|---|---|
| 1. Total number of towns generating significant amount of sewage ( Class I cities and class II towns ) | 222 |
| 2. Sewage generating from these towns | 8,250 MLD |
| 3. Sewage directly disposed into the Ganga River | 2,460 MLD |
| 4. Sewage disposed into tributaries of the Ganga River | 4,570 MLD |
| 5. Sewage disposed on land or low lying areas | 1,220 MLD |

***Sewage Treatment***

| | |
|---|---|
| 1. Sewage Treatment capacity created under Ganga Action Plan Phase-I | 882 MLD |
| 2. Sewage Treatment capacity created along the Yamuna | 2,647 MLD |
| 3. Additional towns where sewage treatment capacity is being created under GAP Phase-II | 48 (600 MLD) |
| 4. Number of towns where sewage treatment capacity is being created on tributaries of the Ganga | 23 (750 MLD) |

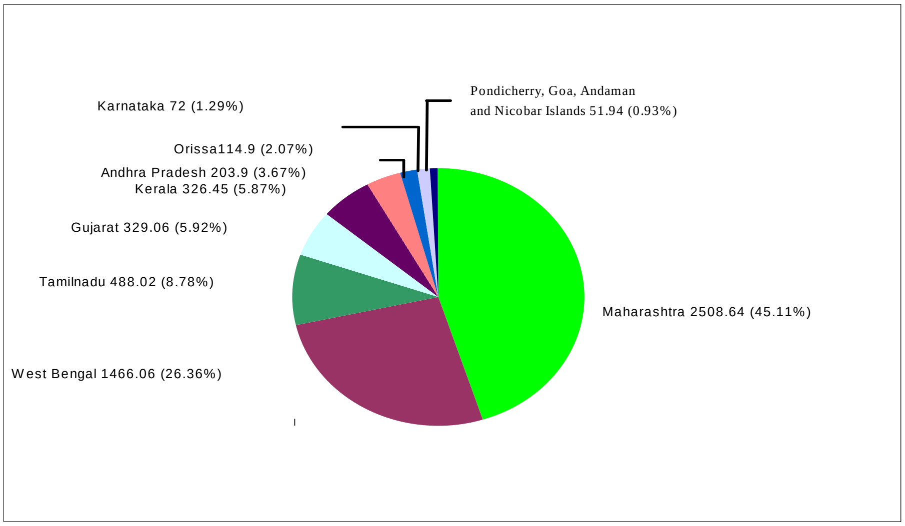
## *Sewage Management in Coastal Cities*

About 60% of the world population live within 60 km of shoreline. India, by virtue of its geographical location, is having 8118 km long coastline. The coastal area accommodates about 25% of country's total population. The wastewater generated from the townships and cities finds its way into the coastal waters including estuaries, creeks, bays etc.

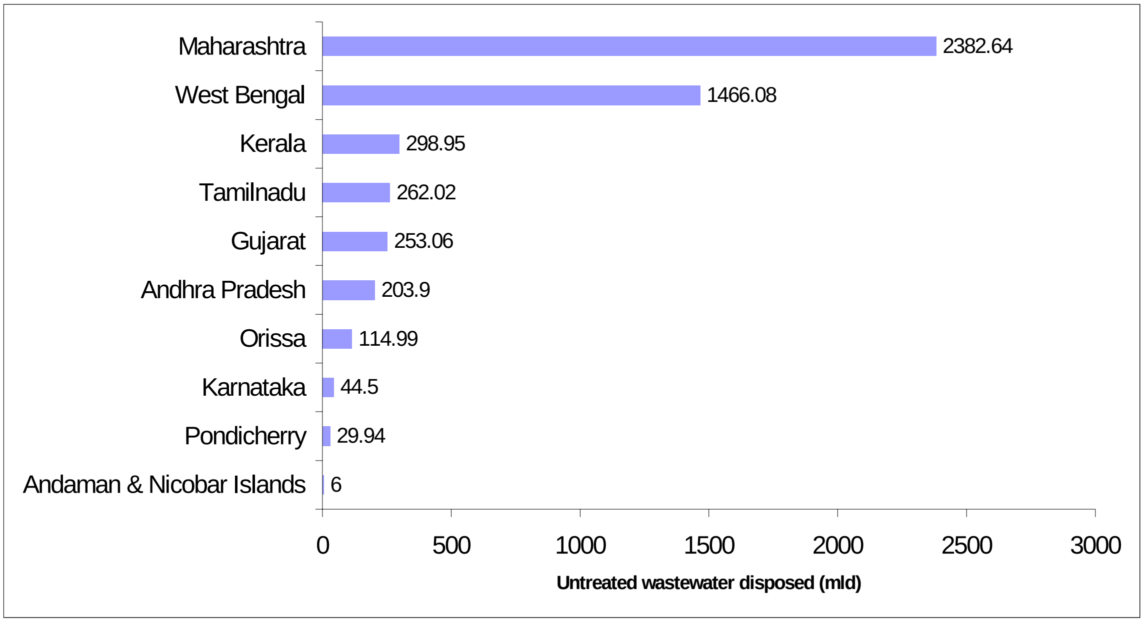
The municipal wastewater constitutes the largest single source of coastal marine pollution. 87 cities and towns located in the coastal areas of the country generate 5560.99 mld of wastewater, which is almost 80% of their total water supply. This quantity is almost 33.37 % of the total quantity of the wastewater generated by 644 class I cities and class II towns in the entire country. The volume of wastewater has increased over two and a half times than the quantity generated two decades ago. Out of this only 78% is collected, while during 1978 the collection was only 46%. About 58.50% of this is generated from the west coast. The State of Maharashtra contributes about 45% of the total wastewater generated by the coastal cities and towns, while the state of West Bengal comes second, contributing about 26%. Thus Maharashtra, West

Bengal and Tamil Nadu generate almost 80% of the wastewater among the coastal states and union territories. Out of 5560.99 mld of wastewater generated only 521.51 mld receives various levels of treatment before letting out to the coastal waters.

Out of the total wastewater generated, 90.62% find its destination into the coastal waters without any treatment. The coastal waters of Maharashtra state receive maximum quantity of untreated municipal wastewater, to the tune of 2382.64 mld followed by the coastal waters of West Bengal, 1466.08 mld from their respective cities and towns.




**State and Union Territory wise generation of municipal wastewater (mld) in coastal cities**




**State and Union Territory wise contribution of untreated municipal wastewater disposed into the coastal waters**

Regarding untreated wastewater disposal, there is a four-fold increase in quantity in a span of two decades. In 1999 the quantity of untreated wastewater disposed to the coastal waters was 5039.48 mld, on the other hand it was only 1264.03 mld in 1978. These problems stem from over population, poor planning and uncontrolled development in the nearby coastal watersheds.

***Sewage Management in Delhi***

It is estimated that out of 3267 mld of sewage generated in Delhi, the treatment capacity is existing for 2330 MLD of sewage (71% of total sewage generation). However, actual treatment is received to only about 1478 mld (63%) of sewage in terms of BOD load. Out of 480 tonnes/day of BOD load generated in Delhi, 264 tonnes/day (or 55%) is reduced due to treatment.

There are 30 STPs located at 17 locations in Delhi. The total combined treatment capacity of all the STPs is 2,330 mld. The actual treatment of sewage during November-December 2003 was observed only 1478 mld, about 63% of the installed treatment capacity.

Out of total STPs, 20 STPs were running under capacity, 5 STPs were running over capacity, 3 STPs were non functional while only 2 STPs are running to their capacity. An attempt was made to evaluate the performance of the STPs in terms of percent reduction in pollution load. Average reduction in BOD, COD and TSS load computed based on the study was 87%, 81% and 92% respectively.

**Status of Sewage Treatment Plants in Delhi during Nov – Dec, 2004**

| Sl. No. | STP's Capacity (MGD) | Design capacity (MLD) | Actual flow (MLD) | Type of STP | Present Status |
|---|---|---|---|---|---|
| 1 | Coronation Pillar STP's<br>(10)<br>(10+20) | <br>45.46<br>45.46<br>90.92 | <br>40.87<br>63.46<br>56.55 | Activated sludge process (ASP), Trickling filter & ASP | Over the Designed Capacity<br>Under Utilized |
| 2. | Delhi Gate (2.2) | 10.00 | 10.00 | High rate biofilters (Densadeg technology | Running on designed capacity |
| 3. | Ghitorni (5) | 22.73 | Nil | - | Not in operation |
| 4. | Keshopur STPs<br>(12)<br>(20)<br>(40) | <br>54.55<br>90.92<br>181.84 | <br>46.55<br>95.10<br>106.46 | All three plants designed on activated sludge process | 12 MGD not running properly sewage passes through PST.<br>Not running<br>Over the Designed Capacity<br>Under- utilized |
| 5. | Kondli STP's<br>(10-Phase-I)<br>(25 -Phase-II)<br>iii. (10-Phase-III) | <br>45.46<br>113.65<br>45.46 | <br>56.55<br>57.96<br>28.36 | All three activated sludge process | <br>Over the capacity<br>Under- utilized<br>Under- utilized |
| 6. | Mehrauli STP (5) | 22.73 | 4.95 | Activated Sludge Process (ASP) | Under-utilized |
| 7. | Najafgarh STP (5) | 22.73 | 2.27 | Activated Sludge Process (ASP) | Under- utilized |
| 8. | Nilothi STP (40) | 181.84 | 15.0 | Activated Sludge Process (ASP) | Under- utilized |
| 9. | Narela STP (10) | 45.46 | 2.50 | Activated Sludge | Under- utilized |

| Sl. No. | STP's Capacity (MGD) | Design capacity (MLD) | Actual flow (MLD) | Type of STP | Present Status |
|---|---|---|---|---|---|
| | | | | Process (ASP) | |
| 10. | Okhla STP's<br>(12)<br>(16))<br>(30)<br>(37)<br>(45) | <br>54.55<br>72.73<br>136.38<br>168.20<br>204.57 | <br>39.09<br>40.91<br>136.98<br>159.11<br>181.84 | All the plants designed on Activated Sludge Process (ASP) | <br>Under- utilized<br>Under- utilized<br>Running in capacity<br>Under-utilized<br>Under-utilized |
| 11. | Papankalan STP (20) | 90.92 | 37.73 | Activated sludge proc. | Under-utilized |
| 12 | Rithala STP's<br>(40) Old<br>(40) New | <br>181.84<br>181.84 | <br>46.28<br>185.07 | <br>ASP<br>UASB | <br>Under-utilized<br>Over the designed capacity |
| 13. | Rohini STP (15) | 68.19 | Nil | Activated sludge process (ASP) | Not in operation |
| 14. | Dr. Sen N.H. STP (2.2) | 10.0 | 10.0 | High rate Bio filter | Running on designed capacity. |
| 15. | Timarpur O.P. (6) | 27.27 | 4.79 | Oxidation ponds | Under-utilized |
| 16. | Yamuna Vihar STP's<br>Ph-I(10)<br>Ph-II(10) | <br>45.46<br>45.46 | <br>27.27<br>14.77 | <br>Activated sludge process | <br>Under-utilized<br>Under-utilized |
| 17. | Vasant Kunj STP's<br>(2.2)<br>(3.0) | <br>10.00<br>13.63 | <br>3.18<br>4.36 | <br>Extended aeration<br>ASP | <br>Under-utilized<br>Under-utilized |
| | **Total** | **2330** | **1478** | **-----** | **-----** |

## SOURCE-RELATED CHARACTERISTICS OF DIFFUSE WATER POLLUTION

*Pollution From Small Rural Hamlets/Villages:* Almost as a rule these would neither have running water supply nor sewered sanitation. In many developing countries (as is the case of India) most people would use open fields for defecation, with a few using pit-latrines or septic-tanks. Much of the bathing and washing (clothes, utensils etc.) shall be in or near the water-body reducing abstraction and transport of water but causing *in-situ* diffuse pollution. Generation of liquid effluents would be minimal and all wastewater generated shall soak into the nearby land. A careful materials-balance as also field experience would show significant quantities of various types of pollutants including salts, nutrients, organics and micro-organisms from such hamlets and rural areas reaching ground or surface water bodies through leachate and as washings in the storm run-offs. On the basis of various experiences, the Central Pollution Control Board estimated an average 15g BOD per capita per day of the rural population reaching the major river draining that particular basin and used this as a basis of computations in its "Basin Sub-Basin Inventory of Water Pollution" series (CPCB 1982-1995). Corresponding loads of salts, nutrients, micro-organic and other pollutants would also be reaching streams and rivers, while the amounts of pollutants percolating to ground waters may be much larger.

*Wastewaters and Pollutants from Unsewered Towns:* For improving standards of life, running water- supply has been established in most of the towns over the past three decades. This has, in turn, led to flush- latrines and much large use of water in homes for bathing, washing of clothes utensils etc, generating significant amounts of wastewaters. Use of soaps and detergents and amounts of various food materials going to the sink have also grown with improved life standards. Unfortunately, sewerage or improved sanitation does not bring the same political dividends in developing countries as running water-supply does. Hence sewerage has lagged far behind the water supply. A large number of the cities/towns either do not have any sewerage system or the sewerage system is overloaded or defunct. All this resulted in large amount of wastewater uncollected. The bulk of pollution shall get retained on land to percolate, leach or get washed-off to streams or groundwater.

*Sewage, Sullage and Pollutants from Urban Areas with Inadequate or Faulty Sewerage and/or Sewage Treatment System:* With exponential growth in urbanisation through migration of the poorest section of populations to cities in search of livelihood, it would be difficult to name many cities or urban areas in developing countries that have adequate and effective sewerage. According to CPCB (1995) only about 40-50% of the populations of the major Indian metro-cities of Delhi, Bombay Calcutta, Madras and Bangalore are served by sewer systems. Even where sewers exist, they often leak or overflow, releasing their contents to storm-water or other surface drains or to percolate in to soil to reach ground-water or streams.

## Future Scenario of Sewage Management

The Population of India is likely to be stabilized by 2050 at the level of 1700 million people. As per the census of 2001 the urban population is 285 million and keeping in view of population projection for the year 2051 is likely to be of the magnitude of 1093 million. The per capita wastewater generation is around 121 litre/capita/day based on the average wastewater generation observed during the three studies carried out by CPCB. Based on the projected population for the year 2051 the wastewater generation is going to be around 132000 mld. As minimum dry weather flow of rivers is going to reduce due to increase in population and as a result increase in water requirements for various purposes, the wastewater generation in any urban centre is going to adversely affect water supply of d/s located urban centres. In view of such situation there is a need to attain 100% wastewater treatment in each city with more stringent standard.

**Projected population and respectively wastewater generation**

| Year | Urban Population | Litres/Capita/Day (lpcd) | Gross Wastewater Generation (mld) |
|---|---|---|---|
| 77-78 | 60 | 116 | 7007 |
| 89-90 | 102 | 119 | 12145 |
| 94-95 | 128 | 130 | 16662 |
| 2001 | 285 | - | - |
| 2011 | 373 | - | - |
| 2021 | 488 | 121 (Assumed) | 59048 (Projected) |
| 2031 | 638 | 121 (Assumed) | 77198 (Projected) |
| 2041 | 835 | 121 (Assumed) | 101035 (Projected) |
| 2051 | 1093 | 121 (Assumed) | 132253 (Projected) |

## CHARACTERISTICS OF DOMESTIC SEWAGE

The design of a sewage treatment works will be dependent on the quality and quantity of the waste to be treated. The following are some of the important characteristics of domestic sewage:

**Organic Matter :** Organic matter is the most important polluting constituent of sewage in respect of its effects on receiving water bodies. It is mainly composed of proteins, carbohydrates and fats. Organic matter is commonly measured in terms of BOD and COD. If untreated sewage is discharged into natural water bodies, biological stabilization of organic matter leads to depletion of oxygen in water bodies.

**Nitrogen & Phosphorus :** Nitrogen and phosphorus are also very important polluting constituents of sewage because of their role in algal growth and eutrophication of water bodies. Nitrogen is present in fresh domestic sewage in the form of proteinaceous matter urea (i.e. organic nitrogen). Its decomposition by bacteria readily changes it into ammonia. In aerobic environments ammonia nitrogen is oxidized into nitrites and nitrates. Nitrates can be used by algae to form plant proteins. Nitrogen is commonly measured as TKN (organic + ammonical) as sewage characteristics. Nitrate and nitrite forms of nitrogen are also measured when quality of receiving/affected water (streams, underground water) is monitored.

Phosphorus is usually present in orthophosphate, polyphosphate and organic phosphate forms. Organically bound phosphorus is of little importance in domestic sewage whereas polyphosphate forms undergo hydrolysis to revert into the orthophosphate forms, although this conversion is quite slow.

**Suspended Solids :** Suspended solids represent that fraction of total solids in any wastewater that can be settled gravitationally. Suspended solids can further be classified into organic (volatile) and inorganic (fixed) fractions. Organic matter is present in the form of either settleable form or non-settleable (dissolved or colloidal) form. If the organic fraction of suspended solids present in sewage is discharged untreated into streams, it leads to sludge deposits and subsequently to anaerobic conditions.

**Dissolved Oxygen :** Dissolved oxygen, as such, does not have any significance as a sewage characteristics. However, it is the most important pollution assessment parameter of the receiving water bodies. Stabilization of organic matter, when discharged untreated or partially treated in receiving waters, leads to depletion of their dissolved oxygen. Nutrients (nitrogen and phosphorus) addition due to discharge of untreated or treated sewage may lead to algal growth in streams. During day time, algae undergo photosynthesis process and the oxygen released by this process is much more than their respiration requirements resulting in a net addition of dissolved oxygen to water. However, during night time photosynthesis process is stopped whereas respiration requirement continues. This leads to depletion of dissolved oxygen in waters. Thus, it is observed that all the polluting constituents of sewage explained above have their direct or indirect effect on dissolved oxygen of receiving waters.

**Bacterial Parameter ( Fecal Coliform ) :** Although organic matter, in dissolved as well as suspended form, is the most important parameter of sewage as far as ecology of receiving water bodies is concerned, Bacterial parameters, such as Fecal Coliform (FC), which serve as indicators of fecal pollution are also very important when human health is the prime concern.

Sewage from large and small towns is discharged either into a water body, which is used for various purposes such as source of drinking water supply and bathing or discharged on land for irrigation, where human beings come in contact with it. Population consuming water from such sources which receive sewage discharges and persons involved in agricultural activities where sewage is applied become vulnerable to infection from pathogenic organisms (mainly bacteria and viruses) which are discharged by human beings who are infected with disease or who are carriers of a particular disease. Thus, to check quality of receiving waters for various uses and to assess acceptability of degree of treatment given to sewage, assessment of bacterial quality also becomes important. Because specific identification of pathogenic bacteria is extremely difficult, the coliform group of organisms is used as an indicator of the presence in wastewater of pathogenic organisms. Coliform bacteria are found in intestinal tract of human beings. Each person discharges about 100 to 400 billion coliform bacteria per day. Presence of coliform organisms is taken as an indication of presence of pathogenic organisms and absence of coliform organism is taken as an indication that water is free from disease producing organisms.

Coliform group of bacteria include genera Escherichia and Aerobacter. Aerobacter and certain Escherichia can also grow in soil and, therefore, use of coliform group of bacteria as indicator of human waste becomes complicated. Difficulty in determining E.coli. to the exclusion of the soil coliform led to use of entire group of coliform as indicator of fecal pollution. Separate determination of Total Coliform (TC), Fecal Coliform (FC) and Fecal Streptococci (FS) is now possible. Presence of FC and pathogenic organism together is well established and FC is the widely used bacterial parameter as indicator of fecal pollution. Determination of FS in waters and wastewaters is also in practice because FC/FS ratio further helps in identification of source. FC/FS ratio for human beings is more than 4, whereas FC/FS ratio for domestic animals is less than 1. Thus FC/FS ratio can be used to find whether suspected contamination of water is derived from human or animal waste. When FC/FS ratio is obtained between 1 to 2 interpretations become difficult. Incidentally, the rate of removal or death of coliform bacteria in waters and wastewaters is parallel to the respective rates for pathogenic intestinal bacteria which makes the use of coliform organisms as indicator of fecal pollution very important. FC is therefore a very important parameter in determing bacterial quality of waters and wastewaters.

A detailed study of all the sewage treatment plants located in Delhi was carried our during November – December, 2003. The analysis of raw sewage (influent to Sewage Treatment Plant) presents a systematic view of its chemical characteristics.

**Characteristics of Sewage in Delhi**
**(As on November-December, 2003)**

| Treatment Plants | Influent Quality | | | | |
|---|---|---|---|---|---|
| | PH | TSS | COD | BOD | Cond. |
| Cor. Pillar(10) | 7.2 | 179 | 317 | 112 | 908 |
| (20+10) | 6.44 | 342 | 172 | 48 | 1700 |
| Keshopur(12*) | Not operational | | | | |
| (20) | 7.3 | 404 | 560 | 282 | 1390 |
| (40) | 7.3 | 404 | 560 | 282 | 1390 |
| Okhla(12) | 7.3 | 498 | 517 | 204 | 1440 |
| (16) | 7.4 | 291 | 486 | 207 | 1510 |
| (30) | 7.4 | 647 | 551 | 222 | 1480 |
| (37) | 7.3 | 480 | 515 | 249 | 1590 |
| (45) | 7.3 | 480 | 515 | 249 | 1590 |
| Narela (10) | 7.4 | 426 | 447 | 100 | 1720 |
| Y. Vihar (Ph.-I 10, | 7.1 | 391 | 505 | 174 | 1110 |
| Ph.-II 10) | 7.2 | 405 | 538 | 199 | 1020 |
| Timarpur O.P -(6) | 6.7 | 412 | 272 | 106 | 1650 |
| Najafgarh (5) | 7.4 | 165 | 205 | 54 | 810 |
| Nilothi (40) | 7.7 | 432 | 328 | 90 | 2340 |
| Dr. Sen N.H.(2.2) | 7.5 | 370 | 585 | 236 | 1680 |
| Delhi Gate (2.2) | 7.5 | 263 | 605 | 147 | 1020 |
| Papankalan (20) | 7.6 | 142 | 275 | 103 | 2190 |
| Kondli Ph.-I (10) | 7.3 | 363 | 507 | 241 | 1390 |
| Ph.-II (25) | 7.3 | 604 | 588 | 261 | 1550 |
| Ph.-III (10) | 7.3 | 519 | 615 | 237 | 1530 |
| Mehrauli(5) | 7.8 | 251 | 326 | 126 | 1090 |
| Rithala {(40 Old) | 7.2 | 330 | 399 | 205 | 1260 |
| (40 New)} | 7.2 | 330 | 399 | 205 | 1260 |
| Vasant Kunj (2.2) | 7.5 | 379 | 460 | 323 | 1710 |
| (3) | 7.4 | 479 | 565 | 306 | 1400 |

## EFFECT OF SEWAGE POLLUTION ON SURFACE WATER BODIES

*Organic Pollution*

All organic materials or wastes can be broken down or decomposed by microbial and other biological activity (biodegradation). Although some inorganic substances are included in this category, most are organic compounds that can exhibit a biochemical oxygen demand (BOD) because oxygen is used in the degradation process. Oxygen is a basic requirement of almost all aquatic life except anaerobic microbes. If sufficient oxygen is not available to the aquatic life, the ecosystem will be adversely affected. Typical sources of organic pollution include sewage from domestic and animal sources; industrial wastes from food processing, paper mills, tanneries, distilleries, sugar and other agro-based industries.

This category of pollution becomes a problem when the oxygen required for biodegradation due to organic pollution is greater than the available oxygen in the water body. Natural systems do have a limited capacity to accommodate self-purification through biodegradation by employing re-oxygenation processes. However, in many situations the anthropogenic pollution overwhelms the given system.

*Effect of Nutrients*

The nutrients are always present in water and thus it supports aquatic life. Here the primary focus is on fertilizing chemicals such as nitrates and phosphates. While important for plant growth, too much of nutrients encourage the overabundance of plant life and can result in environmental damage called "eutrophication". This can occur at both microscopic level in form of algae or macroscopic level in form of larger aquatic weeds. The diurnal change in dissolved oxygen is of serious concern. During day time oxygen remain supersaturated due to photosynthetic contribution of oxygen. But during night the oxygen is depleted as the algal mass consumes significant amount of oxygen. Nitrates and phosphates contributed through anthropogenic sources such as sewage, agricultural run-off and run-off from un-sewered residential areas.

*Effect of High Dissolved Solids (TDS)*

As water is best solvent known on the earth, it can dissolve variety of substances to which it come in contact during hydrological cycle. In natural waters, the dissolved solids mainly consist of bicarbonates, carbonates, sulphates, chlorides, nitrates and phosphates of calcium, magnesium, sodium, potassium with traces of iron, manganese and other minerals. The amount of dissolved solid is important consideration in determining its suitability for irrigation, drinking and industrial uses. In general, waters with a total dissolved solids <500 mg/l are most suitable for drinking. Higher dissolved solids may leads to impairment in physiological processes in the human body. For irrigation water dissolved solid are very important criteria due their gradual accumulation resulting in salinization of soil, thus, rendering the agriculture land non-productive.

Dissolved solids are undesirable in industrial water due to many reasons. They form scales, cause foaming in boilers, accelerate corrosion, and interfere with the colour and tastes of many finished products.

*Effect of Toxic Pollutants on Water Quality*

The toxic Pollutants are mainly heavy metals, pesticides & other industrial xenobiotic pollutants. The ability of a water body to support aquatic life, as well as its suitability for other uses depends on many trace elements. Some metals e.g. Mn, Zn and Cu present in trace quantity are important for the life as it helps and regulates many physiological functions of the body. The same metals, however, causes severe toxicological effects on human health and the aquatic ecosystem. Water pollution by heavy metals resulting from anthropogenic impact is causing serious ecological problems in many parts of the world. This situation is aggravated by the lack of natural elimination processes for metals. Thus, metals shift from one compartment of environment to another, including the biota, often with detrimental effects. Where sufficient accumulation of the metals in biota occurs through food chain transfer, there is also an increasing toxicological risk for man. As a result of absorption and accumulation, the concentration of metals in bottom sediments is much higher than in the water above, which may cause secondary pollution problem. The toxicity of metals in water depends on the degree of oxidation of a given metal ion together with the forms in which it occurs. As a rule, the ionic form of a metal is the most toxic form. However the toxicity is reduced if the ions are bound into complexes with, for example, natural organic matter. Under certain conditions, metallo-organic, low-molecular compounds formed in natural waters exhibit toxicities greater than the uncombined forms. An example is the highly toxic alkyl-derivatives of mercury (methylmercury) from inorganic mercury by aquatic microorganisms. A famous episode of Minamata disease occurred in Japan in fifties due to consumption of fish contaminated by methyl mercury. Metals in natural water can exist in truly dissolved, colloidal and suspended forms. The proportion of these forms varies for different metals and for different water bodies.

Many thousands of organic compounds enter water bodies as a result of human activities. Monitoring every individual compound is not feasible. However, it is possible to select priority organic pollutants based on their prevalence, toxicity and other properties. Mineral oils, petroleum products, phenols, pesticides, polychlorinated biphenyls (PCBs) and surfactants are examples of such compounds. However, these compounds are not universally monitored because their determination requires sophisticated instrumentation and highly trained personnel. Therefore, they are evaluated in terms of toxicity as a summary parameter. Many of these compounds are highly toxic and sometimes are carcenogenic and mutagenic in nature. Some selected compounds are measured by gas chromatography method.

*Ecological Health*

A large number of areas in our aquatic environment support rare species and ecologically very sensitive. They need special protection. Since, the Water Act, 1974 provides for maintenance and restoration of “wholesomeness” of aquatic resources, which is directly related to ecological health of the water bodies, it is important that ecological health of the water bodies is given first priority in the water quality goal.

## HEALTH DIMENSION OF SEWAGE (POLLUTED WATER)

Water-related diseases are a human tragedy, killing millions of people each year, preventing millions more from leading healthy lives, and undermining development efforts. About 2.3 billion people in the world suffer from diseases that are linked to water.

Some 60% of all infant mortality is linked to infectious and parasitic diseases, most of them water-related. In some countries water-related diseases make up a high proportion of all illnesses among both adults and children. In Bangladesh, for example, estimated three-quarters of all diseases are related to unsafe water and inadequate sanitation facilities. In Pakistan one-quarter of all people attending hospitals are ill from water-related diseases.

Providing clean supplies of water and ensuring proper sanitation facilities would save millions of lives by reducing the prevalence of water-related diseases. Thus, finding solutions to these problems should become a high priority for developing countries and assistance agencies.

While water-related diseases vary substantially in their nature, transmission, effects, and management, adverse health effects related to water can be organized into three categories: water-borne diseases, including those caused by both fecal-oral organisms and those caused by toxic substances; water-based diseases; and water-related vector diseases. Another category—water-scarce (also called water-washed)—diseases consist of diseases that develop where clean freshwater is scarce.

***Water-Borne Diseases***

Water-borne diseases are "dirty-water" diseases—those caused by water that has been contaminated by human, animal, or chemical wastes. Worldwide, the lack of sanitary waste disposal and of clean water for drinking, cooking, and washing is to blame for over 12 million deaths a year.

Water-borne diseases include cholera, typhoid, shigella, polio, meningitis, and hepatitis A and E. Human beings and animals can act as hosts to the bacterial, viral, or protozoal organisms that cause these diseases. Millions of people have little access to sanitary waste disposal or to clean water for personal hygiene. An estimated 3 billion people lack a sanitary toilet, for example. Over 1.2 billion people are at risk because they lack access to safe freshwater.

Where proper sanitation facilities are lacking, water-borne diseases can spread rapidly. Untreated excreta carrying disease organisms wash or leach into freshwater sources, contaminating drinking water and food. The extent to which disease organisms occur in specific freshwater sources depends on the amount of human and animal excreta that they contain.

Diarrheal disease, the major water-borne disease, is prevalent in many countries where sewage treatment is inadequate. Instead, human wastes are disposed of in open latrines, ditches, canals, and water courses, or they are spread on cropland. An estimated 4 billion cases of diarrheal disease occur every year, causing 3 million to 4 million deaths, mostly among children.

Using contaminated sewage for fertilizer can result in epidemics of such diseases as cholera. These diseases can even become chronic where clean water supplies are lacking. In the early 1990s, for example, raw sewage water that was used to fertilize vegetable fields caused outbreaks of cholera in Chile and Peru. In Buenos Aires, Argentina, a slum neighbourhood faced continual outbreaks of cholera, hepatitis, and meningitis because only 4% of homes had either water mains or proper toilets, while poor diets and little access to medical services aggravated the health problems.

Toxic substances that find their way into freshwater are another cause of water-borne diseases. Increasingly, agricultural chemicals, fertilizers, pesticides, and industrial wastes are being found in freshwater supplies. Such chemicals, even in low concentrations, can build up over time and, eventually, can cause chronic diseases such as cancers among people who use the water.

Health problems from nitrates in water sources are becoming a serious problem almost everywhere. In over 150 countries nitrates from fertilizers have seeped into water wells, fouling the drinking water. Excessive concentrations of nitrates cause blood disorders. Also, high levels of nitrates and phosphates in water encourage growth of blue-green algae, leading to deoxygenation (eutrophication). Oxygen is required for metabolism by the organisms that serve as purifiers, breaking down organic matter, such as human wastes, that pollute the water. Therefore the amount of oxygen contained in water is a key indicator of water quality.

Pesticides such as DDT and heptachlor, which are used in agriculture, often wash off in irrigation water. Their presence in water and food products has alarming implications for human health because they are known to cause cancer and also may cause low sperm counts and neurological disease. In Dhaka, Bangladesh, heptachlor residues in water sources have reached levels as high as 0.789 micrograms per litre—more than 25 times the WHO-recommended maximum of 0.03 micrograms per litre. Also, in Venezuela a study of irrigation water collected during the rainy season found that the water was contaminated with a number of pesticides. Examination of pregnant women in the area found that they all had breast milk containing DDT residues—toxins that can be passed to an infant.

The seepage of toxic pollutants into ground and surface water reservoirs used for drinking and household use causes health problems in industrialized countries as well. In Europe and Russia the health of some 500 million people is at risk from water pollution. For example, in northern Russia half a million people on the Kola Peninsula drink water contaminated with heavy metals, a practice that helps to explain high infant mortality rates and endemic diarrhoeal and intestinal diseases reported there.

Improving public sanitation and providing a clean water supply are the two steps needed to prevent most water-borne diseases and deaths. In particular, constructing sanitary latrines and treating wastewater to allow for biodegradation of human wastes will help curb diseases caused by pollution. At the least, solids should be settled out of wastewater so that it is less contaminated. It is important that a clean water supply and the construction of proper sanitary facilities be provided together because they reinforce each other to limit the spread of infection.

Many studies link improvements in sanitation and provision of potable water with dramatic reductions in water-related morbidity and mortality. A review in 1991 of over 100 studies of the effects of clean water and sanitation on human health found that the median reduction in deaths from water-related diseases was 69% among people with access to potable water and proper sanitation.

Providing clean water and sanitation greatly reduces child mortality. According to a review of 144 studies from the 1980s, infant and child deaths fell by an average of 55% as a result of providing clean water and sanitation. In a study of countries where infant mortality rates dropped dramatically—as in Costa Rica, where the decline was from 68 deaths per 1,000 live births in the 1970s to just 20 per 1,000 in the 1980s—researchers attributed three-quarters of the mortality decline to water and sanitation projects provided as part of rural community health programs.

While the cost of building freshwater supply systems and sanitation facilities is high, the costs of not doing so can become staggering. In Karachi, Pakistan, for example, a study found that poor people living in areas without any sanitation or hygiene education spent six times more on medical care than people who lived in areas with access to sanitation and who had a basic knowledge of household hygiene.

***Water-Based Diseases***

Aquatic organisms that spend part of their life cycle in the water and another part as parasites of animals cause water-based diseases. These organisms can thrive in either polluted or unpolluted water. As parasites, they usually take the form of worms, using intermediate animal vectors such as snails to thrive, and then directly infecting humans either by boring through the skin or by being swallowed.

Water-based diseases include guinea worm (dracunculiasis), paragonimiasis, clonorchiasis, and schistosomiasis (bilharzia). These diseases are caused by a variety of flukes, tapeworms, roundworms and tissue nematodes, often collectively referred to as helminths, that infect humans. Although these diseases usually are not fatal, they can be extremely painful, preventing people from working and sometimes even making movement impossible. The prevalence of water-based diseases often increases when dams are constructed, because the stagnant water behind dams is ideal for snails, the intermediary host for many types of worms. For example, the Akosombo Dam, on the Volta Lake in Ghana, and the Aswan High Dam, on the Nile in Egypt, have resulted in huge increases of schistosomiasis in these areas. Also, in Mali a survey conducted in 225 villages in different ecological settings found that the prevalence of urinary schistosomiasis was five times greater in villages with small dams (67%) than in the drier savanna villages (13%).

Individuals can prevent infection from water-based diseases by washing vegetables in clean water and thoroughly cooking food. They can refrain from entering infected rivers, because many parasites bore through the feet and legs. In areas where guinea worm is endemic, people can use a piece of cloth or nylon gauze to filter out guinea worm larvae, if clean water is unavailable. As with water-washed diseases, providing hygienic disposal of human wastes helps control water-based diseases. Also, for irrigation channels and other constructed waterways, building fast-flowing streams makes it more difficult for snails to survive, thus eliminating the intermediary host.

Some water-development schemes have started disease control programs along with construction of facilities. In the Philippines, for example, where the development of water resources is a high priority, the National Irrigation System Improvement Project in Layte, begun in 1979, included specific provisions and funding to control schistosomiasis. As a result of these measures, the prevalence of water-based diseases fell from 24% in 1979 to 9% in 1985. Because fewer people fell ill, the average increase in productivity was an estimated 19 days of work per person per year, worth an additional US$1 million in wages.

### *Water-Related Vector Diseases*

Millions of people suffer from infections that are transmitted by vectors—insects or other animals capable of transmitting an infection, such as mosquitoes and tsetse flies—that breed and live in or near both polluted and unpolluted water. Such vectors infect humans with malaria, yellow fever, dengue fever, sleeping sickness, and filariasis. Malaria, the most widespread, is endemic in about 100 developing countries, putting some 2 billion people at risk. In sub-Saharan Africa malaria costs an estimated US$1.7 billion annually in treatment and lost productivity.

The incidence of water-related vector diseases appears to be increasing. There are many reasons: people are developing resistance to antimalarial drugs; mosquitoes are developing resistance to DDT, the major insecticide used; environmental changes are creating new breeding sites; migration, climate change, and creation of new habitats mean that fewer people build up natural immunity to the disease; and many malaria control programs have slowed or been abandoned.

Lack of appropriate water management, along with failure to take preventive measures, contributes to the rising incidence of malaria, filariasis, and onchocerciasis. Construction projects often increase the mosquito population, as pools of stagnant water, even if they exist only briefly, become breeding grounds. For example, in West Africa an epidemic of Rift Valley fever in 1987 has been linked to the Senegal River Project. The project, which flooded the lower Senegal River area, enabled the type of mosquito that carries the virus to expand so much that the virus was transmitted to humans rather than remaining in the usual animal hosts.

The solution to water-related vector diseases would appear to be clear—eliminate the insects that transmit the diseases. This is easier said than done, however, as pesticides themselves may be harmful to health if they get into drinking water or irrigation water. Also, many insects develop resistance to pesticides, and diseases can emerge again in new forms.

Alternative techniques to control these diseases include the use of bednets and introducing natural predators and sterile insects. In Gujarat, India, for example, an important part of an integrated project to control disease vectors was breeding guppies—fish that eat mosquito larvae—in bodies of water, while eliminating the use of insecticides altogether. An inexpensive approach to controlling insect vectors involves the use of polystyrene spheres floating on the top of bodies of static water. Because the spheres cover the surface of the water, the mosquito larvae die from lack of air.

**Water related diseases and Causative factors**

| Name of the disease | Causative organism |
|---|---|
| **1. Water-borne diseases** | |
| **<u>Bacterial</u>** | |
| • Typhoid | *Salmonella typhi* |
| • Cholera | *Vibrio cholerae* |
| • Paratyphoid | *Slmonella parayphi* |
| • Gastroenteritis | Enterotoxigenic *Escherichia coli* |
| • Bacterial dysentery | Variety of *Escherichia coli* |
| **<u>Viral</u>** | |
| • Infectious hepatitis | Hepatitis-A virus |
| • Poliomycetis | Polio-virus |
| • Diarrhoeal diseases | Rota-virus, Norwalk agent, other virus |
| • Other symptoms of enteric diseases | Echono-virus, Coxsackie-virus |
| **<u>Protozoan</u>** | |
| • Amoebic dysentery | *Entamoeba hystolitica* |
| **2 Water-washed diseases** | |
| • Scabies | Various skin fungus species |
| • Trachoma | Trachoma infecting eyes |
| • Bacillary dysentery | *E. coli* |
| **3 Water-based diseases** | |
| • Schistosomiasis | *Schistosoma* sp. |
| • Guinea worm | Guinea worm |
| **4 Infection through water related insect vectors** | |
| • Sleeping sickness | *Trapanosoma* through tsetse fly |
| • Malaria | *Plasmodium* through Anaphelis |
| **5 Infections primarily due to defective sanitation** | |
| • Hookworm | Hook worm, *Ascaris* |

Another way to control the vectors is species sanitation—using biological methods and habitat management to reduce or eliminate the natural breeding grounds of the disease vectors. Such methods can include: filling and draining unneeded bodies of stagnant water; covering water storage containers; eliminating mosquito breeding sites by periodically clearing canals, reservoirs, and fish ponds of weeds; installing sprinkler and trickle irrigation instead of canals; and lining canals to prevent silt deposits from forming and impeding the flow of water. Also, integrating education about disease prevention into health services and encouraging community discussion of prevention would help people to control vectors and to identify and eliminate inconspicuous breeding sites.

### *Water-Scarce Diseases*

Many other diseases—including trachoma, leprosy, tuberculosis, whooping cough, tetanus, and diphtheria—are considered water-scarce (also known as water-washed) in that they thrive in conditions where freshwater is scarce and sanitation is poor. Infections are transmitted when too little fresh water is available for washing hands. These diseases, which are rampant throughout most of the world, can be effectively controlled with better hygiene, for which adequate freshwater is necessary.

Some parasitic diseases not usually considered water-related and previously limited in their reach have been rapidly expanding as populations grow and water supplies become more polluted. For example, cysticercosis, a disease usually produced by tapeworms found in undercooked pork and limited to rural areas, expanded rapidly in Mexico City in the early 1980s. As the city's population soared, the parasite multiplied in the highly polluted water of the Tula River, which supplies much of the drinking water for the makeshift settlements on the city's outskirts. Tens of thousands of people downstream from the city sewage system were infected.

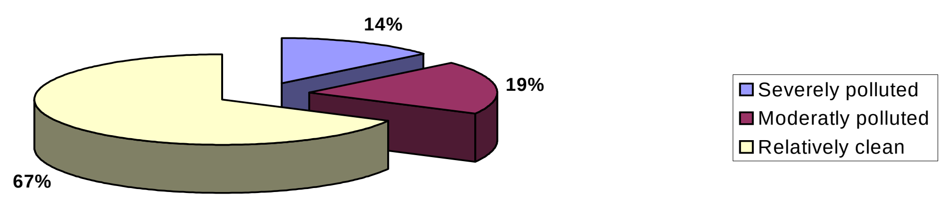
## WATER QUALITY MONITORING

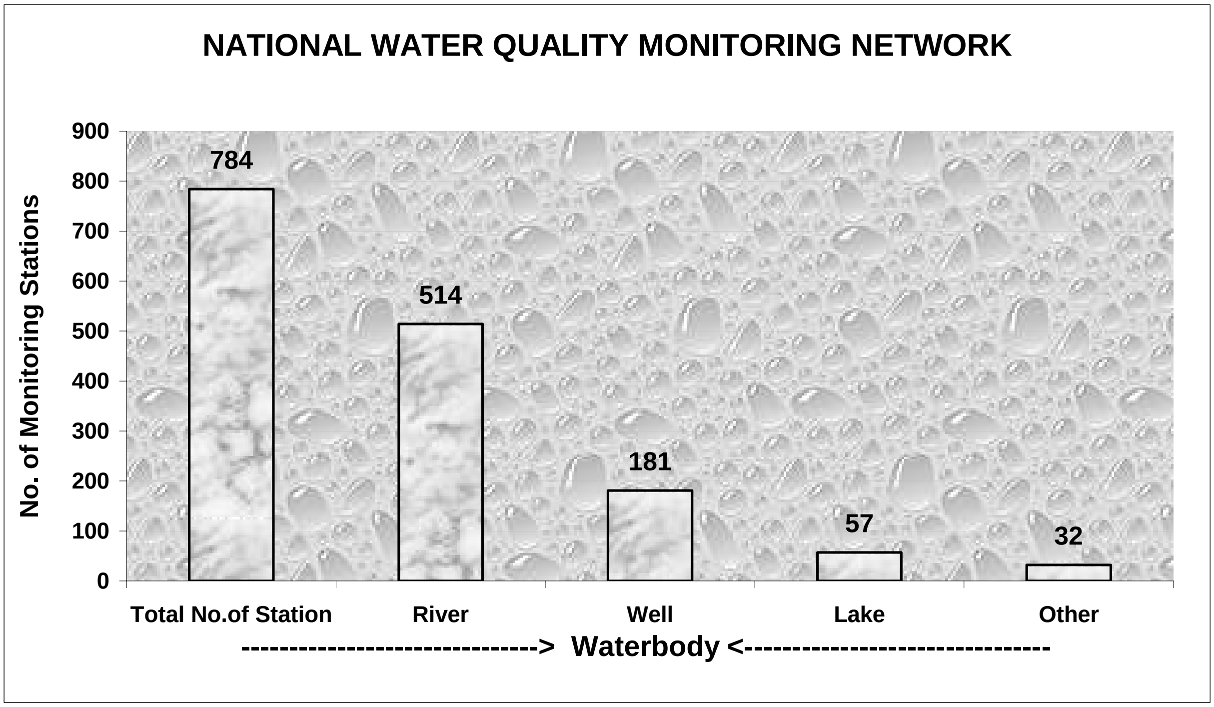
The Central Pollution Control Board in collaboration with State Pollution Control Boards has established a network comprising of 784 stations in 26 States and 5 Union Territories spread over the country for water quality monitoring of aquatic resources. The monitoring is done on monthly or quarterly basis in surface waters and on half yearly basis in case of groundwater. The monitoring network covers 168 Rivers, 53 Lakes, 5 Tanks, 2 Ponds, 3 Creeks, 3 Canals, 12 Drains and 181 groundwater Wells.

The monitoring results obtained during year 2003 indicate that organic pollution continues to be the predominant pollution of aquatic resources. The organic pollution measured in terms of bio-chemical oxygen demand (BOD) and bacterial contamination measured in terms of coliform count give the indication of extent of water quality degradation in different parts of our country. It is observed 67% of the observations, out of nearly 3000 observations are having BOD less than 3 mg/l, 18% between 3-6 mg/l & 15% above 6 mg/l. Similarly Total & Faecal coliform, which indicate presence of pathogens in water, are also of major concern. About 45% observations are having Total coliform and 58% observations show Faecal Coliform less than 500 MPN /100 ml.

The trends of % of observations obtained during year 1994 to 2003 in different levels of pollution with respect to BOD & Total coliform and Faecal Coliform are presented ahead, indicating different ranges of BOD and Coliform organisms. It is clear from the data that there is a increasing trend in percentage of observations having BOD below 3 mg/l. This indicates that there is a gradual improvement in water quality with respect to organic pollution.

**Total riverine length under different levels of pollution in India**



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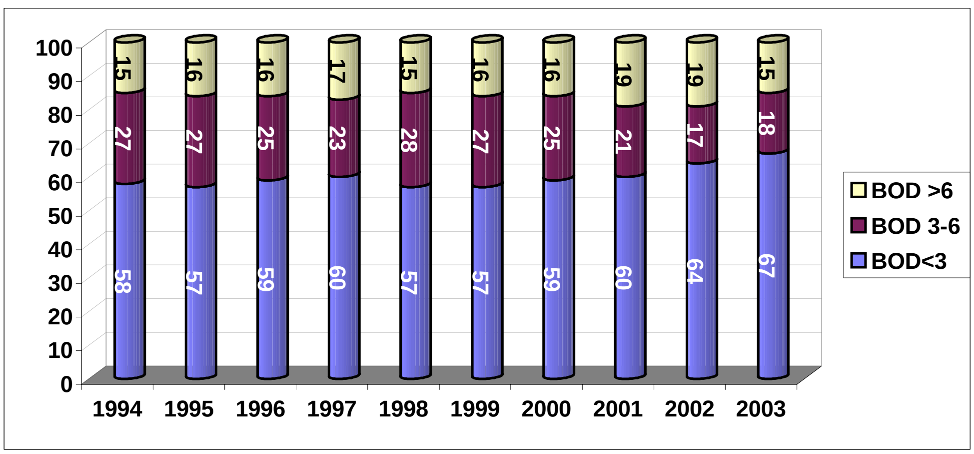
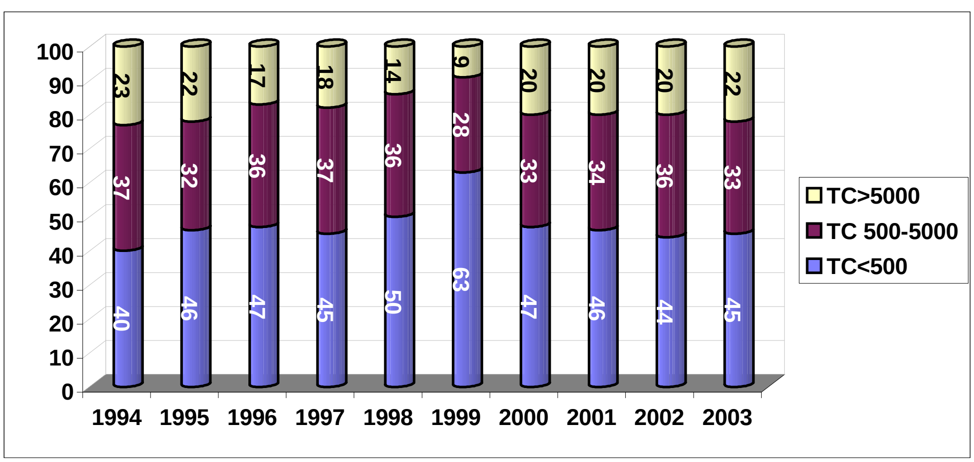
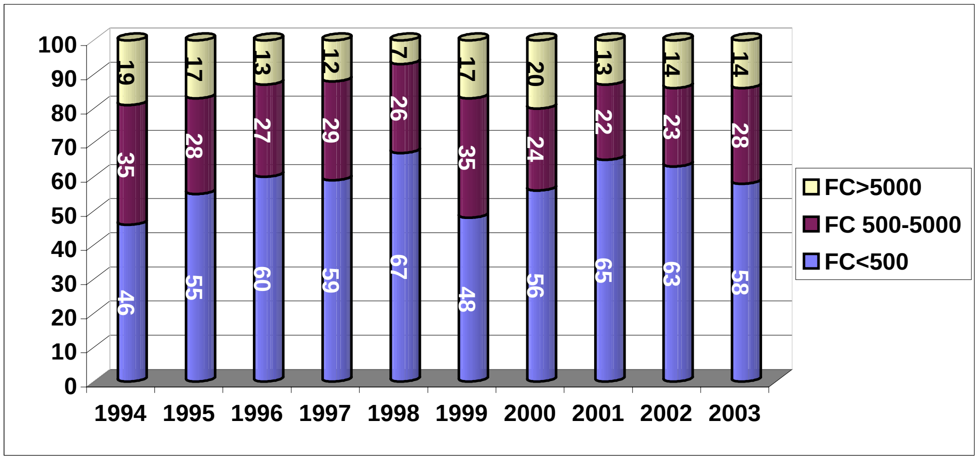
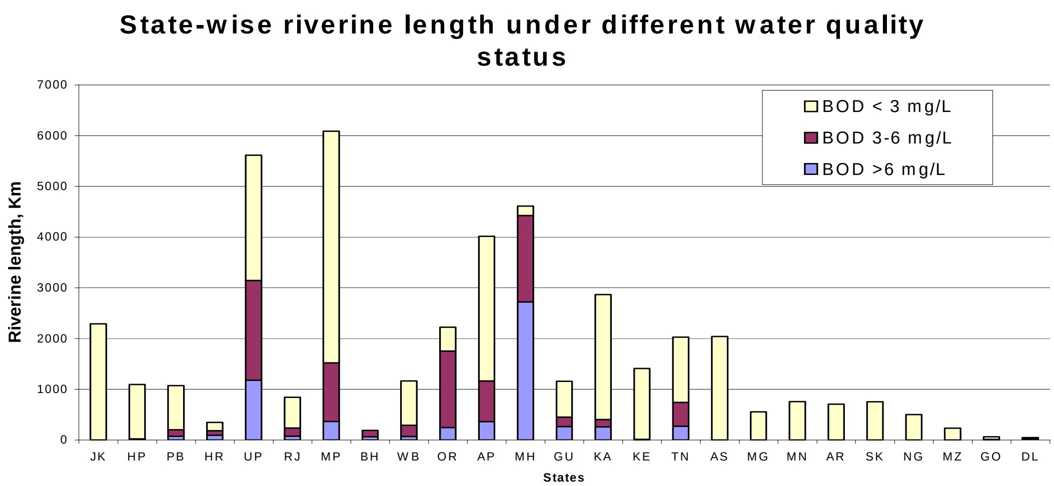
**Water Quality Status & Trend from Year 1994 to 2003**






*BOD: Biochemical Oxygen Demand; TC: Total Coliform; FC: Faecal Coliform*




## TECHNOLOGICAL OPTIONS FOR TREATMENT OF MUNICIPAL WASTEWATER

There are a large variety of treatment techniques designed to remove pollutants from wastewater. The objective of wastewater treatment is to separate wastes from water. In one sense, all wastewater treatment processes can be considered separation processes. There are physical, chemical and biological separation processes. Sedimentation and screening are examples of physical processes. Coagulation, ion exchange and pH adjustment are typical chemical processes, while various forms of biological digestion belong to the category of biological processes. In the biological processes living organisms, while in the physical and chemical processes physical and chemical properties are utilized for waste separation metabolizes organic wastes.

**Major Elements of Wastewater Management Systems and Associated Tasks**

| Elements of Wastewater Management | Associated Tasks |
|---|---|
| Source of generation | Quantification of wastewater, evaluation of techniques of wastewater reduction and determination of wastewater characteristics |
| Source control | Design of onsite systems to provide partial treatment of the wastewater |
| Collection | Design of sewers used to remove wastewater from the various sources of generation |
| Transmission and pumping | Design of large sewers used to transport wastewater to treatment facilities |
| Treatment | Selection, analysis and design of treatment operations and processes to meet specified treatment objectives related to the removal of wastewater contaminants of concern |
| Disposal and reuse | Design of facilities used for the disposal and reuse of treated effluent in the aquatic and land environment, and the disposal and reuse of sludge on land |

Treatment of sewage is accomplished by adopting various treatment schemes, each incorporating one or several different treatment units such as Screens, Grit chambers, Plain Sedimentation, Chemical Precipitation, Trickling Filter, Activated Sludge, Anaerobic digestion, Up flow Anaerobic Sludge Blanket (UASB) reactor, Waste Stabilization Pond and Maturation Pond.

CPCB has carried out a series of studies on performance of Sewage Treatment Plants (STPs) in different parts of the country to evaluate their performance. The findings revealed that a majority of the treatment plants are based on Primary Settling followed by Activated Sludge Process (PS+ASP) technology (with anaerobic digesters for sludge), Oxidation Pond or Waste Stabilization Pond (OP or WSP) technology and UASB followed by Polishing Pond (UASB+PP) technology. Findings have also revealed that most of the STPs are not being utilized to the full capacity due to various reasons.

It has been found that low capital and low operational cost sewage treatment method such as Waste Stabilization Ponds (OP or WSP) technology and low operational cost sewage treatment method such as (UASB+PP) technology are quite effective in BOD removal as well as Fecal Coliform (FC) removal. Overall efficiency of STPs based on these low cost technologies in terms of BOD and FC removal can be further improved if effluent suspended solids (SS) are controlled by improvement in final outlet structures. These technologies are best suited for towns and small cities.

In such situations where sewage of a large city is discharged into a receiving water body having insufficient dilution and/or requires to be maintained at high bacteriological quality, the conventional sewage treatment schemes based on (PS+ASP) technology need augmentation with tertiary treatment units for further removal of BOD and FC . Low cost tertiary treatment method such as series of Polishing Ponds is the best option for tertiary treatment. However if land availability is a constraint then other tertiary treatment options such as coagulant aided flocculation+tertiary sedimentation (TS), TS+Filtration, TS+Chlorination may be adopted.

**Conventional wastewater treatment**

Conventional wastewater treatment consists of pretreatment, primary sedimentation, secondary biological treatment, secondary sedimentation and chlorination before being discharge. Historically, biological techniques have been widely utilized since they are generally economical to build and operate as composed to physico-chemical techniques. Moreover, they are more efficient as natural means of treatment are utilized in optimized conditions.

Treatment systems could be classified according to the degree of pollutant removal into pretreatment, primary, secondary, tertiary and ultimate treatment. They could be classified according to the means of pollutant removal into biological or physico-chemical treatment. Essentially, pretreatment and primary treatment involves screening and grit removal, equalization and the removal of high concentration of solids that might decrease the efficiency of subsequent treatment processes. The term secondary treatment is commonly used to describe any of the following biological processes: activated sludge, extended aeration, trickling filters, aerobic and anaerobic lagoons and anaerobic and facultative (mixed) ponds. In the typical aerobic process the removal of oxygen-demanding dissolved organics through microorganisms takes place.

Organic material + Bacteria + Oxygen → More bacteria

Organic material + Bacteria + Oxygen → $CO_2$ + $H_2O$ + Stabilized residual

In an activated sludge process, the incoming waste effluent is continuously fed into biological reactor (aeration tank) in which bacterial mass, in a desired concentration, is maintained in suspension. Organic matter in the incoming effluent is partially oxidized by the bacterial mass and partially converted to excess sludge. The sludge in the out-flow of aeration tank is then separated in a clarifier. This sludge is continuously recycled back to the aeration tanks, however, a portion of sludge (excess sludge) is sent to the sludge beds for drying and in this way a desired concentration is maintained. The conventional type activated sludge process could remove as much as 85% of the BOD load.

The extended aeration is essentially similar to the activated sludge process, but yields less sludge for disposal. Through sufficient retention time, biological solids are oxidized, thus minimizing resultant sludge.

In aerobic lagoons, oxygen is usually supplied through surface aerators that keep solids in suspension, allowing for about 50 to 60 percent BOD removal.

Trickling filters are packed with rocks, on the surface of which bacteria are allowed to grow, while wastewater is trickled over through nozzles, allowing for consumption of dissolved organics by bacteria. The relative effectiveness in BOD removal of trickling filters is relatively low compared to other secondary treatment systems.

Tertiary treatment aims at further removal of BOD, suspended solids etc., as well as colour, nitrates, phosphates and other pollutants not adequately removed by secondary treatment processes. Tertiary treatment could involve carbon adsorption, coagulation and sedimentation, ion exchange, membrane filtration, and other processes.

**Treatment Processes and Purpose of each Process in a Treatment System**

| **Principal purposes of Unit Processes** | **Unit Processes** |
|---|---|
| Grit Removal | Grit Chambers |
| Removal or grinding of coarse solids | Bar Screens |
| Odour control | Perchlorination, Ozonation |
| Gross solids-liquid suspension, BOD reduction | Plain primary settling |
| Gross removal of soluble BOD and COD from raw wastewater | Biological treatment |
| Removal of oxidized particulates and biological solids | Plain secondary settling |
| Decomposition or stabilization of organic solids, conditioning of sludge for dewatering | Anaerobic sludge digestion |
| Ultimate sludge disposal | Sludge drying beds, land disposal, land reclamation |
| Removal of colloidal solids and turbidity from wastewater | Chemical treatment, sedimentation, mixed-media filtration |
| Phosphates removal | Chemical coagulation, flocculation and settling |
| Nitrate removal | Ammonia stripping |
| Removal of suspended and colloidal materials | Mixed-media filtration |
| Disinfections | Chlorination, UV treatment |

## OPTIONS FOR ADOPTION OF NEW TREATMENT METHODS

### Upflow Anaerobic Sludge Blanket (UASB)

Among the high rate reactors for wastewater treatment, the UASB process has gained popularity in recent years all over the world. Under the Ganga Action Plan, this system is installed at Kanpur and Mirjapur. Several distilleries in the country have also adopted UASB treatment system because of its advantage over the conventional treatment. In the last 20 years, over 150 UASB units have been built in the world for treating high BOD industrial wastes (distilleries sugar, milk etc.). Since 1982, their use has been extended to include typical municipal sewage which has a relatively low BOD of only 200-300 mg/l. The world's first full-scale demonstration plant for municipal sewage was built in Kanpur, India in 1989 (5 mld capacity) under the Indo-Dutch project. This is working successfully. Subsequently, under the same project, a 14 mld unit was designed and built in Mirzapur (UP) and another 36 mld unit is commissioned for Kanpur to treat sewage mixed with tannery wastes. A similar plant of 50 mld capacity is being designed for Hyderabad City sewage as a part of its master planning for Hyderabad with the World Bank funding. The advantages and contraints of UASB system are as follows:

*Advatnages :*

The hydraulic retention time is only 8-10 hrs,No prior sedimentation is required, The anaerobic unit does not need to be filled with any stones or other media, The upflowing sewage itself forms millions of small "granules" which are held in suspension and thus provide large surface area, No mixer or aerators are required, thus conserving energy and operation cost,the gas produced can be collected and used, Daily operation of UASB requires minimum attention, No special instrumentation is necessary for control, and Surplus sludge is easy to dry. The UASB has already secured acceptance in the new edition of CPHEEO's Manual of Sewerage & Sewage Treatment Practice (1993) and it is expected to pick-up faster. It will depend on the success of plants already installed and acceptance by those who have been accustomed to waste water treatment plants with sizable investment in construction. The UASB system is uncommonly simple and it does not require elaborate equipment and construction activities.

*Constraints :*

The most difficult problem with the UASB system is corrosion. Hence, all construction materials used to be carefully chosen. The UASB is not yet widely used in India. Its application for treatment of municipal wastewater is only 6 years old and the manipulates are not geared to adopt new technologies. However, its applications in industry are increasingly rapidly. Through the Ganga Action Plan, a begining has been made which will be consolidated in the National River Action Plan.

**Two-Stage, Aerobic Unitank System (TSU-System):**

The two stage, aerobic Unitank system and the tri-stage, anaerobic-aerobic Unitank system with biological nitrogen removal (3SU - N System) has been developed in Europe. This is a cost-effective alternative to conventional activated sludge systems. The main advantages are reduction in capital and operational costs, flexible and reliable operation and high process performance. After the preliminary treatment (screening, grit removal equalization, no primary settling) the wastewater is first treated in a high loaded combined aeration-sedimentation stage. The BOD reduction is about 80-85%. The partially purified water then flows by gravity to a low loaded combined aeration-sedimentation stage where the residual BOD is removed to obtain a high quality effluent resulting in more than 98% removal of BOD.

*Advantages:*

(a) Less capital costs, No primary settling, Less total aeration volume, No separate sedimentation tanks, No sludge scraping, No sludge recycling facilities Rectangular tanks, compact construction possible, full use of available land, cheaper and easier to construct as compared to circular tanks, economical lengths of connecting pipes and channels, Compact system: smaller land area required.

*Natural or naturally based wastewater treatment technologies are defined as those that employ natural processes (biological, physical or solar elements) to achieve a desired level of treatment. Naturally-based approaches usually have one or more of the following characteristsics:*
*- Achieving acceptable level of treatment*
*- Requiring low capital investment*
*- Requiring low ongoing operation and maintenance costs*
*- Requiring less-skilled operator knowledge than many conventional technology*
*- Potentially having longer life-cycles than conventional electro-mechanical technology*

(b) Less operational costs, Less energy for aeration, No energy for sludge recycle, Less maintenance costs (less moving parts).

(c) Better process performance, High treatment efficiency, Control of sludge bulking, Simple and reliable process, reduced need for supervision.

(d) Easily controlled by microprocessor

(e) Flexible operation, Flexibility of temporary operation with half capacity, Restoration of full capacity without long time lag, Possible applications, brewing and malting wastewater treatment, Municipal wastewater treatment, Food processing wastewater treatment, Industrial wastewater treatment, Aerobic post treatment of anaerobic effluents from distilleries.

**Root Zone Treatment:**

The process is a natural way of treating industrial or domestic wastes. The method developed in Sixties in Germany, is now commercialized for treatment of domestic and industrial wastewater, economically and efficiently. It has got three integrated components; reeds, reed bed and microbial organisms. In this system, contaminated water is allowed to flow underground through the root zones of especially designed reed beds. The reeds and the reed bed on the soil the surface provide an efficient treatment system. The reed bed serves as the host for more than 2000 species of bacteria and thousands of fungal species. These microbial organisms oxidise the organic matter both aerobically as well as anaerobically. Phosphate, sulphur and carbon compounds, nitrogenous materials reduce to their elemental forms. Heavy metals precipitate from solution and are bound into the soil matrix. Due to the high biodiversity of microbes, the root-zone system is capable of shock loads.

The root zone system is suitable for concentrations from a few mg/l upto 20,000 mg/l of COD & 4000 mg/l of nitrogen. It can be built for effluent throughout from about $lm^3$/day to more than 10,000 $m^3$/day. For domestic sewage the land requirement is around 0.2 $m^2$/person. But for the larger area requirement as compared to conventional methods, the root zone treatment system offers an ideal option for biological effluents because of its simplicity and ruggedness. Even in areas where land is a constraint, the system could be adopted with innovations like vertical treatment facility.

**Land treatment for waste management**

While indiscriminate discharge of wastes on land is an issue of serious environmental concern, it needs to be recognised that land is he best available sink for ultimate disposal of wastes. This becomes particularly relevant in the context of a developing country where it is unlikely that all the wastes would be provided fullest treatment at source before their disposal.

Controlled application of wastes on land can help in achieving a desired degree of treatment through the physical, chemical and biological processes within the plant-soil-water matrix. Partially treated waste water can be further treated through land application and land can serve as a 'living filter' comprising interaction of soil, vegetation cover and soil micro-organisms.

The various purposes for which land application could be resorted are :

* Extraction of useful constituents in the wastes to provide plant nutrients or soil amendments.
* Revegetation and reclamation of degraded lands,
* Dedicated disposal of recalcitrant wastes.

Depending on the methods of application and percolation, the land treatment of wastes may be of three types viz : Slow Rate System, Rapid Infiltration System and Overland Flow System.

To ensure safety and precautionary measures in land treatment of wastes, it is essential to ascertain the background concentration of pollutants, possible fate of the pollutants added to the land and the risks involved in terms of assimilative capacities and acceptable limits. Decisions in this regard are to be necessarily guided by a clear understanding of the reaction processes and transport phenomena within and among various sinks namely living systems, soil, water and air. Pilot projects undertaken in selected areas have shown encouraging results based on which it is possible to establish cost effective approaches for waste management through land treatment.

## SEWAGE UTILIZATION

### Land Application of Wastewater

Broadly, land application can be defined as a technique which utilizes the interaction between natural soil, vegetation and wastewater to upgrade the quality of wastewater. The traditional sewage farming with innovations to suit location specific conditions could be a cost effective method for treatment and utilization of waste water. The value of wastewater as a substitute of organic manure in agriculture (also of water in arid regions) has been recognized for over a century but its use has been restricted by the constraints of social acceptability and the high incidence of diseases in human beings. The municipal sewage has very high economic value. In our country, nearly half of the sewage generated is used for irrigation. The major constraints in sewage farming practices are as follows :

**(a)** Application of raw (untreated) sewage on land causes serious problems of stinking odour, water logging and mosquito breeding.

**(b)** Long term application of sewage effluents and/or sludge results in accumulation of chlorides, sulphates and toxic elements like cadmium, Nickel, copper, chromium, manganese, arsenic and mercury in the soil, and consequently reduce crop growth. Irrigation generally results in gradual building up of salinity and this is accelerated by the use of municipal wastewater. Changes in soil texture and consequent water logging also may occur in certain areas.

**(c)** Depending upon the soil texture and the flow velocity of water through the soil layers, the nutrients (especially nitrates), organic toxic substances and also the pathogens (bacteria and viruses) move to the groundwater.

Human population engaged in agriculture and fish farms supplied with municipal wastewater and sludge are directly exposed to the pathogens which cause different diseases. Several reports show that upto 70% of the farm workers suffer from helminth infection. Further risks to human health arise from the consumption of food contaminated with pathogens and toxic substances directly or through the food chain.

***Nutrients in Human Waste Compared to Nutrients in Commercial Chemical Fertilizers (Mid 1990s)***

| ***Country*** | ***Nutrient equivalent in commercial fertilizer (percent)*** |
|---|---|
| *Kenya* | *136* |
| *Tunisia* | *25* |
| *Indonesia* | *49* |
| *Zimbabwe* | *38* |
| *Columbia* | *31* |
| *Mexico* | *31* |
| *South Africa* | *29* |
| *Egypt* | *28* |
| *India* | *26* |

Studies show that the municipal sewage can be used profitably provided that the treatment procedures ensure that the sludge and municipal wastewater do not contain significant amounts of pesticides, detergents, heavy metals and pathogenic organisms. Conventionally, treated sewage appears best suitable for raising tree plantations, horticultural use (watering public gardens and roadside trees) and growing such plants which are tolerant to various pollutants and are not consumed directly by humans and cattle.

The effects of using municipal wastewater in forestry are not well known and therefore, long term studies are required on the impacts of sewage application on the tree growth, other biota and soil characteristics.

The utilization of sewage is also limited by the climate and soil types. Whereas sewage irrigation can be readily recommended in areas with limited water resources seasonally or throughout the year, it is not possible to utilize the effluents in high rainfall regions and during the rainy season elsewhere. Soils prone to salinity and water logging are not suitable whereas many wastelands can possibly be reclaimed with the sludge and sewage effluents.

Another major problem in sewage utilization is that of the long distances to which the sewage or the treated effluents have to be transported as the areas under agriculture and forestry are far off from the urban centers. Decisions about the location of treatment plants have to take into account a number of factors like the location of the urban centers and their physiographic features. The periodic failure of the treatment plants as well as their overflow during the rainy season also create problems in the utilization, and hence, better management of the treatment facilities is essential.

## Use of Sewage in Pisciculture

Sewage contains all the essential major and minor fertilizing elements normally used in fish culture. Being in a digested and hence available form, its nutrients promote rapid growth of fish food organisms, which in turn results in greater production of fish per unit area. Fish spawn immediately after stocking needs plentiful supply of natural food in the form of planktons of restricted size, preferably rotifers and cladocerans. Unfortunately, fish culture has not yet been regarded as a means for recycling sewage effluents. It is extensively used in certain parts of the country as a convenient and cheap means of fertilizing the ponds and as such little money is spent on proper treatment. Sewage fed fish culturing is still to gain popularity on a wider scale although these are in the experimental stage at various research centres.

A number of field and experimental studies, particularly in West Bengal and Tamil Nadu have demonstrated that the utilization of the nutrients in the domestic sewage by aquaculture is profitable, and that using a favourable fish species, with judicious management and correct harvesting techniques, very high yields of fish can be obtained.

## Sewage Utilization in Forestry

Though considerable effort has been made towards the utilization of municipal wastewater and sludge in natural forests as well as plantations in North America (Cole et al. 1986), it has received hardly any attention in India. Often suggestions have been made for applying sludge and irrigation with sewage effluents in tree plantations, orchards, gardens, lawns, golf courses and similar areas (Shende 1982, Kali and Swaminathan 1980), there is no information on the suitable species, their responses at different growth stages and adverse impacts, if any. A study in Haryana showed that sewage with a high concentration of heavy metals can be better used in forestry (Baddesha and Chhabra 1985) as the woody species normally grown are sturdy and the problems of toxicity, heavy metals and salinity stress are relatively negligible. As these are not consumed directly by humans or animals, no major hazards to life should be expected. Eucalyptus, Leuacnea and Poplar species have been recommended for plantation under sewage irrigation through ridges and trenches where water is not allowed to stagnate (Chhabra 1988).

## Use of Vermiculture for Waste Management

Recently, verticulture technology (use of earth worms for bioconversion of wastes) has been used for the management of garbage, kitchen wastes, organic wastes from food industries etc. The effect of organic matter on earthworm populations and the ability of earthworms to promote the decomposition of organic matter have been described for decades. A combination of recycling and resource recovery through biogas and vermiculture could yield fuel (methane fertilizer (biogas plant effluents and nutrient rich vermucasts (and feed (worm biomass). Recently, the Central Pollution Control Board sponsired a project on development of design criteria for a small community sewage treatment plant based on vermiculture technology. The project was carried out by the Bhawalkar Earth Research Institute, Pune. According to the findings of the project, for sewage with less than 700 $g/m^3$ COD, a vemiflter can be designed with a hydraulic loading of only 0.5 $m^3$. For dilute waste water, hydraulic loading is the controlling factor governing the requirement of vernifitter area. On the other hand, for strong waste water containing more than 500 g/$m^3$ organics (equivalent to 700 g/m3 COD), the area requirement is to be governed by the organic loading. This needs further research to optimize the technical & economical aspects.

## DECENTRALISED SMALL SCALE TREATMENT SYSTEMS

Promoting the development of decentralized wastewater treatment and recovery technologies that are linked with urban agriculture systems, at the neighbourhood level, appear to be a national approach to solving the human and environmental health dilemmas that result from under –managed wastewater. Decentralized small scale systems must be considered in planning and upgrading urban environments. Gravity flow, small bore sewage, and water borne conveyance systems offer the potential to decentralize urban environments into catchment systems, each with their own integrated treatment plants and at low costs. These systems would be based on the topography of the local water shed, and would result in small–scale facilities equally dispersed through environment. Pathogenic reduction and nutrient recovery would occur through the use of integrated biological processes, which are also low cost. This approach would allow for independent, self maintained, and self sustained facilities that are capable of recovering wastewater resources and immediately reusing them in decentralized urban farms.

The replication of centralised, highly engineered human waste management systems resultant of sanitary reforms of the 19th century have not been successful in many developing world contexts. Many reports suggest that emergent trends in low-cost, decentralised naturally-based infrastructure and urban wastewater management that promotes the recovery and reuse of wastewater resources are increasingly relevant. The concept of managing urban wastewater flows at a decentralised or "intermediate" level, based on micro-watersheds is being explored. The concept of planning integrated wastewater management strategies in conjunction with an urban agricultural "waste-sink" is suggested as a rational approach to waste management and the conservation of valuable urban resources.

*Transformation of Urban Waste Management*

Urban waste management must be transformed from a disposal-based linear system to a recovery-based closed-loop system that promotes the conservation of water and nutrient resources and contributes to public health. Moreover, it is apparent that both the knowledge and the technology exist, can enable this transformation. There is a gap, however, between the current availability of innovative technology and the promotion/financing of demonstration level projects as well as the development of complementary socioeconomic methodologies to facilitate their implementation.

Conventional and highly engineered wastewater management technologies and strategies often focus on electro-mechanical solutions that are capital intensive and require ongoing capital investments for effective operation. Additionally, these systems have shorter life-cycles compared to many alternative and naturally-based technologies which also offer opportunities for resource recovery.

The development of zero-discharge urban wastewater management strategies will contribute to a reduction in the pathogenic contamination of surface and groundwater and aid in protecting the vitality of urban dwellers. Organic waste recovery can result in production inputs for urban agriculture, enhance food security and link different sectors of local economies. De-centralised, organic waste recovery systems that integrate the best available low-technology in the recovery of urban domestic wastewater flows are essential and appropriate components in the promotion of a comprehensive urban ecosystem health strategy.

*Low Cost Systems*

In the case of domestic wastewater, individual household are the polluters, and as per the concept of "polluter pays", every polluter should accept the burden of wastewater treatment. In the decentralised treatment system, a balance between the advantages of large scale treatment in terms of economics of scale and individual responsibility for domestic wastewater treatment can be obtained by providing colonywise/sectorwise treatment system. It does not necessarily mean the low cost treatment systems like root zone treatment, stabilization ponds, septic tanks and imhoff tanks, wherein installation cost and operation and maintenance cost of such treatment system are low in comparison with conventional energy intensive treatment system. Sometimes high-tech systems are also required for such projects. Each treatment technology has got its advantages and disadvantages and any technology for treatment should be selected after taking all necessary considerations.

**Merits & Demerits of Different Low-cost Wastewater Treatment Systems**

| Type | Kind of treatment | Use for type of wastewater | Advantages | disadvantages |
|---|---|---|---|---|
| Septic tank | Sedimentation, sludge stabilization | Wastewater of settleable solids, especially domestic | Simple, durable, little space because of being underground | Low treatment efficiency, effluent not odourless |
| Imhoff tank | Sedimentation, sludge stabilization | Wastewater of settleable solids, especially domestic | Durble, little space because of being underground, odourless effluent | Less simple than septic tank, needs very regular desludging |
| Anaero-bic filter | Anaerobic degradation of suspended and dissolved solids | Pre-settled domestic wastewater of narrow COD/BOD ratio | Simple and fairly durable if well constructed and wastewater has been properly pre-treated, high treatment efficiency, little permanent space required because of being underground | Costly in construction because of special filter material, blockage of filter possible, effluent smells slightly despite high treatment efficiency |
| Baffled Septic tank | Anaerobic degradation of suspended and dissolved solids | Pre-settled domestic wastewater of narrow COD/BOD ratio, | Simple and durable, high treatment efficiency, less space required because of being underground, hardly any blockage, relatively cheap | Less efficient with weak waste water, longer start-up phase than anaerobic filter |

| Type | Kind of treatment | Use for type of wastewater | Advantages | disadvantages |
|---|---|---|---|---|
| | | | compared to anaerobic filter | |
| Root Zone Treatment System | Aerobic facultative – anaerobic degradation of dissolved and fine suspended solids, pathogen removal | Suitable for domestic wastewater where settleable solids and most suspended solids already removed by pre-treatment | High treatment efficiency when properly constructed, pleasant landscaping possible, no wastewater above ground, no nuisance of odour | High space requirement, great knowledge and care required during construction, intensive maintenance and supervision during first 1-2 years |
| Anaerobic pond | Sedimentation, anaerobic degradation and sludge stabilization | Domestic and strong and medium wastewater | Simple in construction, flexible in respect to degree of treatment, little maintenance | Wastewater pond occupies open land, there is always some odour, can even be stinky, mosquitoes are difficult to control |
| Aerobic pond | Aerobic degradation, pathogen removal | Pre-treated domestic wastewater | Simple in construction, reliable in performance if proper dimensioned, high pathogen removal rate, can be used to create an almost natural environment, fish farming possible when large in size and low loaded | Large space requirement, mosquitoes and odour can become a nuisance if undersized, algae can raise effluent BOD |
| Duck-weed Pond | Anaerobic except aerobic at top, Degradation of Suspended and dissolved Solids, Nutrient Removal | Sullage or Pre-treated sewage | Simple in construction, Revenue generation through pisciculture, suitable for rural and semi–rural area | High space requirement, possibility of odour can not be ruled out, proper harvesting of duckweed is must. |

**Centralised Vs. Decentralised Systems**

Domestic wastewater management of any city consists of collection, treatment and disposal. In conventional centralised sewage treatment system, about 80% of the cost is accounted for the collection alone. The cost of collection of sewage and its conveyance to one terminal point in the larger cities is very high. Further, the depth of sewer goes on increasing with the increase in length of sewer line and pumping of the sewage at intermediate and terminal points requires a lot of energy. Further centralised treatment systems or conventional systems aggravate the environmental problem, as large volume of the wastewater of the entire city is discharged at one place.

In many situations, on site treatment and storage systems (e.g. anaerobic treatment-technologies and septic tanks) can be effectively used for the management of wastewater, but they require periodic emptying and the sludge must be transported to agro production units, In Calcutta wetlands are more than 3,000 ha in size, and are the site of the world largest traditional system for treating domestic wastewater and fertilizing fish production ponds is purified through a variety of nature forces (chemical , physical and solar), which act synergistically to achieve waste water treatment. A series of shallow ponds act as stablisation lagoons, while water hyacinth act to accumulate heavy metals and multiple forms of bacteria, plankton and algae act to further purify the water.

Most recently the term ecological engineering has been used is describe the treatment of waste water in ecologically based "green machines" or "living machines". The development of solar technologies and an increased understanding of the role of organisms in water purification process is providing both economic and environmental benefits. In these systems, enclosed greenhouses enhanced the growth of algae, plants & bacteria which in turn, act to degrade the biological and pathogenic components of waste water effluent.

Mechanised or conventional treatment systems are efficient, in terms of their spatial requirements (0.5-1 $m^2$ / Person Equivalent, PE - compared to natural treatment systems at 5-10 $m^2$/ PE), but depend on economies of scale to make them economically feasible. Electro-mechanical wastewater treatment technologies designed to remove high levels of biological oxygen demand (BOD) are not only huge capital investments, but also pose certain dilemmas if reuse of treated effluents is to be an option. Conventional, aerobic, treatment results in maximum reductions in BOD and nutrients while it is desirable to retain biomass BOD and nutrients for agricultural production. Often, the removal of pathogens requires chemical inputs to meet disinfection guidelines, which increases the operation cost and complexity of the system. Dependence on chemical disinfection also complicates effluent reuse in non-restricted irrigation schemes when compared to low-cost solutions such as wastewater stabilisation ponds (WSP), which are economical, produce similar reductions in BOD, nutrients, and greater pathogen reduction, but at a fraction of the cost.

Natural treatment technologies are considered viable because of their low capital costs, their cost of maintenance, their potentially long life cycle compared to electro-mechanical solution and their ability to recover a variety of resources.

**Recommendations for Decentralised Systems**

To propagate the concept of Decentralised Sewage Treatment System in the country a national workshop was organised on 24th January 2003. The recommendations of the workshop are as follows:

*Policy and Rules for Promoting Decentralised Sewage Treatment System (DTS)*

1. In view of the critical problem of increasing contamination of surface and groundwater and of the solid-mantle due to untreated or inadequately treated wastewaters and the unsatisfactory performance of the municipalities in handling the problems of existing dwellings, all new housing constructions should provide for appropriate treatment, recycling, reuse or disposal of the wastewater generated by them. This could be on the basis of a colony, co-operative group of houses or individual houses. The proposals should be cleared by the municipal

and pollution control authorities who would also be responsible for monitoring after commissioning of the system.

2. Consent to establish to be made mandatory for new townships or residential colonies, on the line of industry.
3. Use of EIA/EMP tool for township and residential colonies also to be encouraged.
4. For new piped water supply project, corresponding capacity of sewage treatment in terms of Decentralized Treatment System (DTS) or augmentation of STP capacity should be associated as part of the project.
5. Special standards for DTS under the Environment (Protection) Act, 1986/ the Water (Prevention & Control of Pollution) Act, 1974 may be considered.
6. Provision for DTS by developers may find place in municipal bylaws and Municipal Act.
7. Town planning in respect of sewerage and drainage network should be planned in such a way that it has scope for DTS.
8. Decentralized treatment should form part of development plan for all new settlement programme.
9. The designers and builders for sewerage/drainage systems should be made responsible for the treatment & utilization of wastewaters on long-term basis.
10. AICTE may consider including courses on DTS, Diffused Pollution Control, Environmental Protection and Pollution Control Rules & regulations in Degree & Diploma curricula.

*Economic Incentives for DTS*

1. Price for water supply may have two components

   a. for fresh water supply; and

   b. for sewage treatment.

   And the community which has DTS may be supplied water at lower cost.

2. The Resident Welfare Associations (RWAs) should be made responsible for operation and maintenance (O & M) of DTS and should be given rebate in house tax.

3. In the absence of clear policy framework from the government for DTS and since the recycling of treated wastewater only partially meets the O & M costs, the onus of meeting the O & M costs rests with public/people who set up DTS in colonies. The government in such a situation should provide immediate rebate in property/house tax for those participating in DTS in order to promote DTS.

4. Land development charges levied has a component for sewerage network, which should be kept separate and be spent on DTS or centralized STP.

*Demonstration Projects, Documentation and Dissemination*

1. Demonstration plants using onsite DTS should be promoted/funded throughout the country for which progressive builders and Resident Welfare Associations may show the way.

2. Pilot and nodal schemes should be promoted by MOEF/CPCB.

3. The development authority like DDA may install DTS at two colonies. Based on the experience, policy may be made for implementation in other colonies in future.

4. Mass awareness and public participation needs to be promoted.

5. Documentation and dissemination of case studies/practical experiences need to be taken up on a wider scale.

6. Advertisement in Press and on Television, Radio for Environment friendly sewage treatment for all housing colonies should be planned in such a way that it has scope for DTS.

*Technology and Operation & Maintenance*

1. Sewage fed lakes/ponds in urban centers may be converted to DTS so that water quality of lakes and ponds are improved.

2. Proper operation and maintenance of DTS to increase the social acceptance.

3. 'Polluters Pay Principle' should be adopted for O & M of the treatment plants.

4. Segregation & reuse of wastewater at household level be encouraged.

5. Resource recovery like energy should be part of technology to make the system sustainable.

6. Technology selection should be on case-to-case basis and the Auroville, Themax & Panchsheel Club, Delhi experience can be useful.

7. The decentralized treatment plant construction and O & M responsibility should be given to specialist agencies that can take the responsibility for technology risk.

8. People who contribute wastewater should be a party right from planning, construction to operation & maintenance.

## STANDARDS FOR DISCHARGE OF SEWAGE

| S. No. | Parameter | Standards | | | |
|---|---|---|---|---|---|
| | | **Inland surface water** | **Public sewers** | **Land for irrigation** | **Marine/coastal areas** |

| | 2 | | | 3 | |
|---|---|---|---|---|---|
| | | (a) | (b) | (c) | (d) |
| 1. | Colour and odour | See 6 of Annexure-I | - | See 6 of Annexure-I | See 6 of Annexure-I |
| 2. | Suspended solids mg/l, max. | 100 | 600 | 200 | (a) For process waste water<br>(b) For cooling water effluent 10 per cent above total suspended matter of influent. |
| 3. | Particle size of suspended solids | shall pass 850 micron IS Sieve | - | | (a) Floatable solids, solids max. 3 mm<br>(b) Settleable solids, max 856 microns |
| 4. | pH value | 5.5 to 9.0 | 5.5 to 9.0 | 5.5 to 9.0 | 5.5 to 9.0 |
| 5. | Temperature | shall not exceed $5^0$C above the receiving water temperature | - | - | Shall not exceed $5^0$C above the receiving water temperature |
| 6. | Oil and grease, mg/l max, | 10 | 20 | 10 | 20 |
| 7. | Total residual chlorine, mg/l max. | 1.0 | - | - | 1.0 |
| 8. | Ammonical nitrogen (as N), mg/l, max. | 50 | 50 | - | 50 |
| 9. | Total kjeldahl nitrogen (as N); mg/l, max. | 100 | - | - | 100 |
| 10. | Free ammonia (as NH3), mg/l,max. | 5.0 | - | - | 5.0 |
| 11. | Biochemical oxygen demand (3 days at $27^oC$), mg/l, max. | 30 | 350 | 100 | 100 |
| 12. | Chemical oxygen demand, mg/l, max. | 250 | - | - | 250 |
| 13. | Arsenic(as As). | 0.2 | 0.2 | 0.2 | 0.2 |
| 14. | Mercury (As Hg), mg/l, max. | 0.01 | 0.01 | - | 0.01 |
| 15. | Lead (as Pb) mg/l, max. | 0.1 | 1.0 | - | 2.0 |
| 16. | Cadmium (as Cd) mg/l, max | 2.0 | 1.0 | - | 2.0 |
| 17. | Hexavalent chro-mium (as Cr + 6), mg/l, max. | 0.1 | 2.0 | - | 1.0 |
| 18. | Total chromium (as Cr) mg/l, max. | 2.0 | 2.0 | - | 2.0 |

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| S. No. | Parameter | Standards | | | |
|---|---|---|---|---|---|
| | | Inland surface water | Public sewers | Land for irrigation | Marine/coastal areas |

| | 2 | | | 3 | |
|---|---|---|---|---|---|
| | | (a) | (b) | (c) | (d) |
| 19. | Copper (as Cu) mg/l, max. | 3.0 | 3.0 | - | 3.0 |
| 20. | Zinc (as Zn) mg/l, max. | 5.0 | 15 | - | 15 |
| 21. | Selenium (as Se) | 0.05 | 0.05 | - | 0.05 |
| 22. | Nickel (as Ni) mg/l, max. | 3.0 | 3.0 | - | 5.0 |
| 23. | Cyanide (as CN) mg/l, max. | 0.2 | 2.0 | 0.2 | 0.2 |
| 24. | Fluoride (as F) mg/l, max. | 2.0 | 15 | - | 15 |
| 25. | Dissolved phos-phates (as P), mg/l, max. | 5.0 | - | - | - |
| 26. | Sulphide (as S) mg/l, max. | 2.0 | - | - | 5.0 |
| 27. | Phenolic compounds (as $C_6H_50H$) mg/l, max. | 1.0 | 5.0 | - | 5.0 |
| 28. | Radioactive materials: | | | | |
| | (a) Alpha emitters micro curie mg/l, max. | $10^{-7}$ | $10^{-7}$ | $10^{-8}$ | $10^{-7}$ |
| | (b)Beta emitters micro curie mg/l | $10^{-6}$ | $10^{-6}$ | $10^{-7}$ | $10^{-6}$ |
| 29. | Bio-assay test | 90% survival of fish after 96 hours in 100% effluent | 90% survival of fish after 96 hours in 100% effluent | 90% survival of fish after 96 hours in 100%effluent | 90% survival of fish after 96 hours in 100% effluent |
| 30. | Manganese | 2 mg/l | 2 mg/l | - | 2 mg/l |
| 31. | Iron (as Fe) | 3mg/l | 3 mg/l | - | 3 mg/l |
| 32. | Vanadium (as V) | 0.2 mg/l | 0.2 mg/l | | 0.2 mg/l |
| 33. | Nitrate Nitrogen | 10 mg/l | - | - | 20 mg/l |

**Note:**

1. *6 of Annexure I states that "all efforts should be made to remove colour and unpleasant odour as far as practicable"*
2. *These standards shall be applicable only if such sewer leads to a secondary treatment including biological treatment system otherwise the discharge into sewers shall be treated as discharge into inland surface waters.*

## WHAT YOU CAN DO TO MINIMIZE SEWAGE POLLUTION

* Don't hose down your lawn or corridor to clean it. Sweep it off.

* Run your dishwasher, washing machine, and dryer only when you have full loads.

* When possible, use an outdoor clothesline instead of a clothes dryer.

* When it comes time to buy or replace the one you already own, consider a front-loading washing machine. Front loaders will use up to 40 per cent less water than a comparable top-loading model.

* Fix leaks promptly. A dripping joint can waste more than 76 litres of water a day.

* Install low-flow shower-heads.

* Take showers instead of baths. Showers use less water - if you limit them to five minutes.

* Turn off the tap! Running the tap while shaving, brushing teeth, or washing dishes wastes about 10 litres of water every minute.

* Install a `greywater' tank to reuse some household water that might otherwise go down the drain.

* Cut down on pesticide use in the lawn and garden - only one per cent of pesticides actually reach a pest. Consider using organic pesticides.

* `Xeriscape' your lawn. The term refers to a method of landscaping that uses the least amount of water. Plant grass, shrubs and flowers that require little water and use other techniques that conserve water.

* **Do not leave food in the plate – this may help reducing BOD load of Yamuna by 40 tonnes per day in Delhi alone.**

## DEFINITIONS OF WORDS OR TERMS

**Activated Sludge:** Flocculent sludge produced by the growth of bacteria and other organisms in raw or settled sewage, when it is continuously aerated.

**Activated Sludge Process:** A biological treatment process in which a mixture of sewage and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated sewage by settlement and may be re-used.

**Aerobic action:** A biological process promoted by action of bacteria in the presence of dissolved oxygen.

**Anaerobic action:** A biological process promoted by the action of bacteria in the absence of dissolved oxygen.

**Biochemical Oxygen Demand (BOD):** The amount of dissolved oxygen consumed by micro-biological action when a sample is incubated, usually for 5 days at 20 deg. C (expressed as BOD5 ) or for 3 days at 27 deg. C (expressed as BOD3).

**Biological Filter:** A bed of relatively inert material to promote or assist natural aerobic degradation of sewage.

**Biological Treatment:** This is a stage in the treatment of sewage or other effluents which biologically treats the pollution frequently by the natural aerobic degradation of the pollutant.

**Chemical Oxygen Demand:** The amount of oxygen used in the chemical oxidation of the matter present in a sample by a specified oxidising agent under standard conditions.

**Colloidal Material:** The finely divided solids which will not settle but which may be removed by coagulation.

**Crude Sewage:** Sewage which has received no treatment.

**Digestion:** The biochemical decomposition of organic matter using anaerobic bacteria, which results in the formation of simpler and less offensive compounds.

**Dosing Chamber:** A small tank which receives settled sewage until the desired quantity has accumulated, when it is discharged automatically to the distributor of a biological filter.

**Drains:** These are usually the smaller pipes that serve a single property, and they join up to form a Drainage System. There may be foul water, and surface water drains, which are usually in separate systems. Many queries are caused by drainage problems, and odours or smells from these systems.

**Effluent Polishing or Tertiary Treatment:** A further stage of treating sewage or effluents, by removing suspended solids and or pollutants. Consequential removal of suspended solids may also remove residual BOD or other pollutants.

**Eutrophication:** The enrichment of water in watercourses and lakes by chemical substances, especially compounds of nitrogen and phosphorous.

**Filter medium:** The material of which the biological filter is formed and on which a biological film (or biomass) containing bacteria and fungi develops.

**Final Effluent:** The effluent discharged from a sewage treatment plant.

**Membrane:** New technology has been developed whereby the pollutants in liquids can be removed by the use of ultra fine membranes, such as the Reverse Osmosis method in the treatment of fresh potable water, or membranes in the treatment of polluted water or effluents.

**Odours:** Sewage by its very nature will produce odours, and these can sometimes be a problem at sewage pumping stations or sewage treatment works.

**Oxidation:** The chemical change which a substance undergoes when it takes up oxygen.

**Primary Settlement Tank:** A tank, in which the majority of settleable solids are removed from the crude sewage that will flow into it.

**Reed Beds:** These are usually specially constructed beds which contain reeds (frequently the *Phragmites Australis* reed ) to biologically treat sewage and other effluents. Many natural reed beds exist in wetland areas.

**Rotating Biological Contactor (RBC):** This is a system of sewage or effluent treatment, that uses closely spaced parallel discs mounted on a horizontal shaft, which rotate about a horizontal axis, and the discs are alternatively exposed to polluted liquors and air as the shaft rotates to biologically treat the sewage.

**Secondary Settling tank:** A tank in which settleable solids or humus is separated from the effluent flowing through it, from biological filters or other biological treatment units.

**Septic Tank:** A type of settlement tank in which the sludge is retained for sufficient time for the organic matter to undergo anaerobic decomposition.

**Settling (or Sediment) Tank:** This is a tank which is used in the treatment of sewage or effluents to settle out the suspended solids contained in the liquids. The tank may be sited near the works inlet as a 'primary settlement tank' or alternatively after biological treatment as a final (humus) settlement tank.

**Sewage:** The water-borne wastes of a house or community.

**Sewage Treatment Works:** The site which contains all the necessary plant for the treatment of sewage.

**Sewage Treatment Plant:** The items of equipment or structures which treat the sewage.

**Sewerage:** This term is used to describe such items as a 'sewerage system' or 'sewerage network'. (for example - sewage runs in a sewerage system.)

**Sludge:** A mixture of solids and water produced during the treatment of waste water or sewage. This will frequently have to be removed from the treatment system by de-sludging.

**Sludge Removal or De-Sludging:** This is the process of removing sludge from treatment systems or tanks and can be carried out manually or automatically. All sludge's removed from tanks or systems should be transported with care and in accordance with current legislation.

**Storm Sewage (or Surface Water Sewage):** Sewage flowing to a treatment works in wet weather or discharged from storm overflows when the sewage is diluted with rainwater.

**Suspended Solids (SS ):** Solids in suspension in sewage liquors as measured by filtration through a filter paper followed by washing and drying.

**Tertiary Treatment:** There are many differing types of tertiary treatment of effluents, the most common being, Grass Plots, Reed Beds, Upward flow Clarifier. Rapid Gravity Sand Filter, Microstrainer, Sand Filter, Drum Filter, Lagoons, Nitrifying Filter.

**Toxicity :** This usually refers to the toxic element of waterborne wastes, and the toxic elements may comprise of metals, pesticides, or other chemicals which cause pollution of streams, watercourses, rivers, beach's, or ground water.

**Water Quality:** This term is used to describe the quality of water in rivers, lakes, streams or watercourses, as well as the quality of Potable or Drinking Water

**Wetlands:** Many natural wetland areas exist throughout the world and these are frequently found where this is some form of pollution that they use as a nutrient feed. In some areas these natural wetlands have been constructed by man to treat sewage or other forms of effluent pollution.

## FURTHER READINGS


| | |
|---|---|
| CUPS/4/1978-79 | Status of Water Supply and Wastewater Collection, Treatment & Disposal in Class-I Cities – Status & Action Plan |
| CUPS/6/1978-79 | Status of Water Supply and Wastewater Collection Treatment & Disposal in Class-II Towns of India |
| CUPS/30/1989-90 | Status of Water Supply and Wastewater Collection, treatment and Disposal in Class-I Cities |
| CUPS/31/1989-90 | Status of Water Supply and Wastewater Collection, treatment and Disposal in Class-II Town |
| CUPS/41/1994-95 | Management of Municipal Solid Wastes - Status and Options |
| CUPS/42/1996-97 | Status of Water Supply & Waste Water Generation, Collection, treatment and Disposal in Metrocities |
| CUPS/44/1998-99 | State of Water Supply and Wastewater Generation, Collection, Treatment and Disposal in Class – I Cities |
| CUPS/45/99-2000 | Sewage Management in Trans-Yamuna Region of Delhi : Status and Needs |
| CUPS/49/99-2000 | Status of Water Supply and Wastewater Generation, Collection, Treatment and Disposal in Class-II Towns |
| CUPS/54/02-03 | Status of Sewage Treatment Plants in Ganga Basin |
| PROBES/80/2001-02 | Guidelines for Health & Safety of Workers in Wastewater Treatment Facilities |

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|---|---|
| PROBES/83/2001-02 | Status Report on Dinapur Sewage Treatment Plant and Surroundings |
| COPOCS/27/2002-03 | Municipal Sewage Pollution Along Indian Coastal Waters |
| MINARS/21/2002-03 | Water Quality Status & Trends (2000) |
| PCLS/2/1992 | Pollution Control Acts, Rules & Notifications issued thereunder |
| PCLS/4/1994-95 | Environmental Standards for Ambient Air, Automobiles Fuels, Industries and Noise |
| ADSORBS/32/99-00 | Water Quality Status of Yamuna River |
| CPCB Annual Report | Various Years |
| CPCB Highlights | Various Years |

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