Urban water quality Management

with reference to Urban Lake Water Quality Restoration & Management in India

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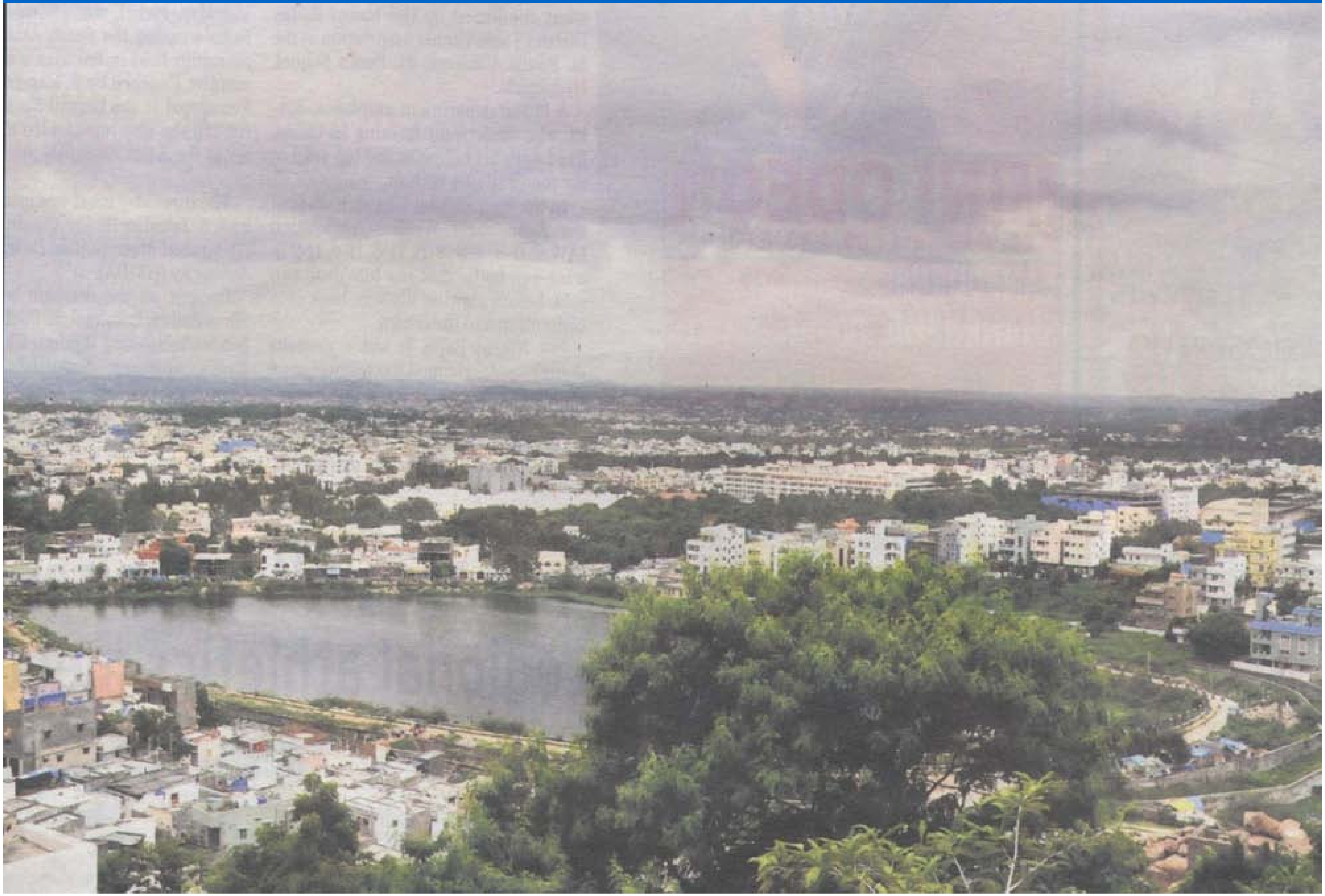
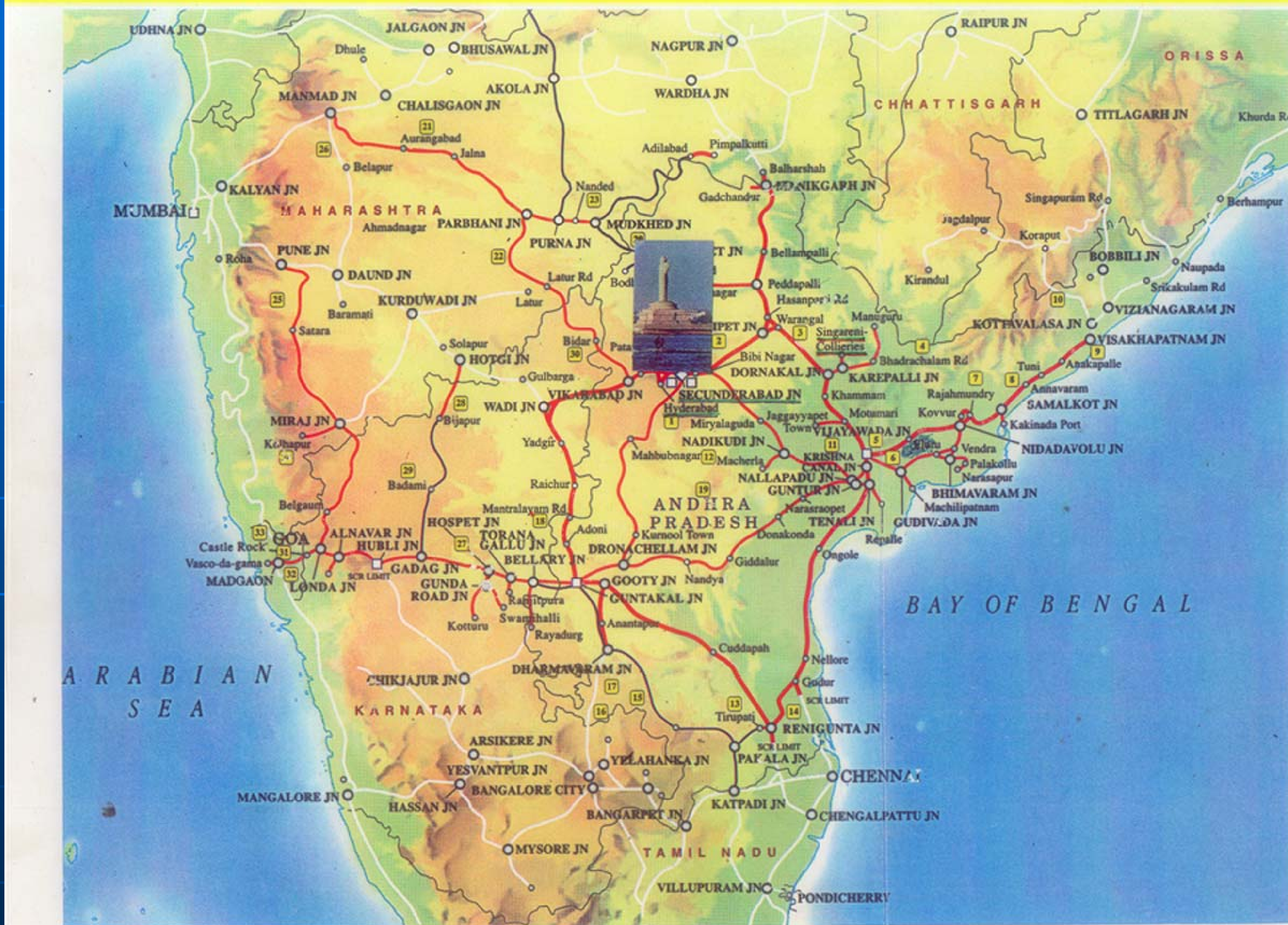
An Overview of an Urban Lake




UDHNA JN
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BHUSAWAL JN
Dhule
NAGPUR JN
RAIPUR JN
ORISSA
AKOLA JN
WARDHA JN
MANMAD JN
CHALISGAON JN
CHHATTISGARH
TITLAGARH JN
Khurda Rd
Aurangabad
Jalna
Adilabad
Pimpalkutti
Belapur
Balharshah
KALYAN JN
Nanded
Gadchandur
Singapuram Rd
Berhampur
MUMBAI
MAHARASHTRA
PARBHANI JN
MUDKHED JN
Jagdalpur
Ahmadnagar
Koraput
PURNA JN
Bellampalli
BOBBILI JN
PUNE JN
Roha
DAUND JN
Latur Rd
Peddapalli
Kirandul
Naupada
Srikakulam Rd
KURDUWADI JN
Baramati
Latur
VIZIANAGARAM JN
Warangal
Manuguru
KOTTAVALASA JN
Satara
Solapur
Bidar
Singareni Collieries
VISAKHAPATNAM JN
HOTGI JN
Bibi Nagar
Bhadrachalam Rd
Tuni
Anakapalle
Gulbarga
DORNAKAL JN
KAREPALLI JN
Annavaram
VIKARABAD JN
SECUNDERABAD JN
Khammam
Rajahmundry
SAMALKOT JN
WADI JN
Hyderabad
Jaggayyapet Town
Motumari
Kovvur
Kakinada Port
MIRAJ JN
Bijapur
Miryalaguda
VIJAYAWADA JN
Kolhapur
Yadgir
NADIKUDI JN
NIDADAVOLU JN
Mahbubnagar
Macherla
KRISHNA CANAL JN
Vendra
Palakollu
Narasapur
NALLAPADU JN
Raichur
Badami
GUNTUR JN
BHIMAVARAM JN
Belgaum
Machilipatnam
Mantralayam Rd
ANDHRA PRADESH
Narasraopet
HOSPET JN
Adoni
TENALI JN
GUDIVADA JN
ALNAVAR JN
GOA
Kurnool Town
Donakonda
Castle Rock
HUBLI JN
TORANAGALLU JN
Repalle
BELLARY JN
DRONACHELLAM JN
Vasco-da-gama
GADAG JN
Giddalur
Ongole
MADGAON
LONDA JN
SCR LIMIT
GUNDA ROAD JN
GOOTY JN
Nandya
Rayadurg
GUNTAKAL JN
BAY OF BENGAL
Swamihalli
Kotturu
Anantapur
Cuddapah
Nellore
ARABIAN SEA
CHIKJAJUR JN
DHARMAVARAM JN
Gudur
KARNATAKA
Tirupati
RENIGUNTA JN
ARSIKERE JN
YELAHANKA JN
PAKALA JN
YESVANTPUR JN
CHENNAI
BANGALORE CITY
MANGALORE JN
HASSAN JN
BANGARPET JN
KATPADI JN
CHENGALPATTU JN
MYSORE JN
TAMIL NADU
VILLUPURAM JN
PONDICHERRY

EXTERNAL LOADING OF NUTRIENTS

- Nutrients are usually present in small amounts in the natural aquatic systems (or unpolluted waters), which are essential for maintaining a balanced ecosystem.

- But, these nutrients are present in abundance in municipal sewage & wastewater, and agricultural runoff (which flow down to the receiving water bodies), the former known as direct & point source of pollution, and the later known as indirect & non-point source of pollution. (Reddy et al, EMA 2012)

Effects on Aquatic Systems with External Loading of Nutrients

- Municipal sewage (MS) depletes the DO, causes severe B.O.D., malodor, and contributes various pathogens into the receiving water bodies.
- According to Indian CPCB, about 74 percent of MS generated in cities and towns in India is released untreated into urban lotic & lentic systems, e.g., Ganga, Yamuna & Godavari, etc., and Dal Lake, Pitchola, Hussainsagar (A. P.) and Ooty (T. N.) and other Lakes.

Effects of Input Municipal Sewage

- The inflow of both treated and untreated raw municipal sewage into the receiving water bodies showed significant spatial and temporal effects on the major nutrients – Nitrate (NO_3), Phosphate (PO_4), Sulphate (SO_4), Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), and also dissolved oxygen (DO) of the water

[Kumar and Reddy, 2008]

What is water quality?

Water quality is defined as:

"Numerical description of Physical, Chemical and Biological conditions of a Water Body. It is a measure of water body's ability to support beneficial use" (ecosystem services)

Stoddard et al., 2002.

Water quality conditions

- **Physical:**

  Temperature, Total suspended solids, dissolved solids, Turbidity, Color

- **Chemical:**

  pH, EC, Dissolved Oxygen, BOD, COD, Ammonia-N, Nitrite-N, Nitrate-N, Phosphate, heavy metals and pesticide residues, etc.

- **Biological:**

  Micro-, Meio- or Meso- and Macro-organisms, *viz,* virus, bacteria, planktons, protozoa, arthropod larvae, insects, fishes, amphibians, etc.

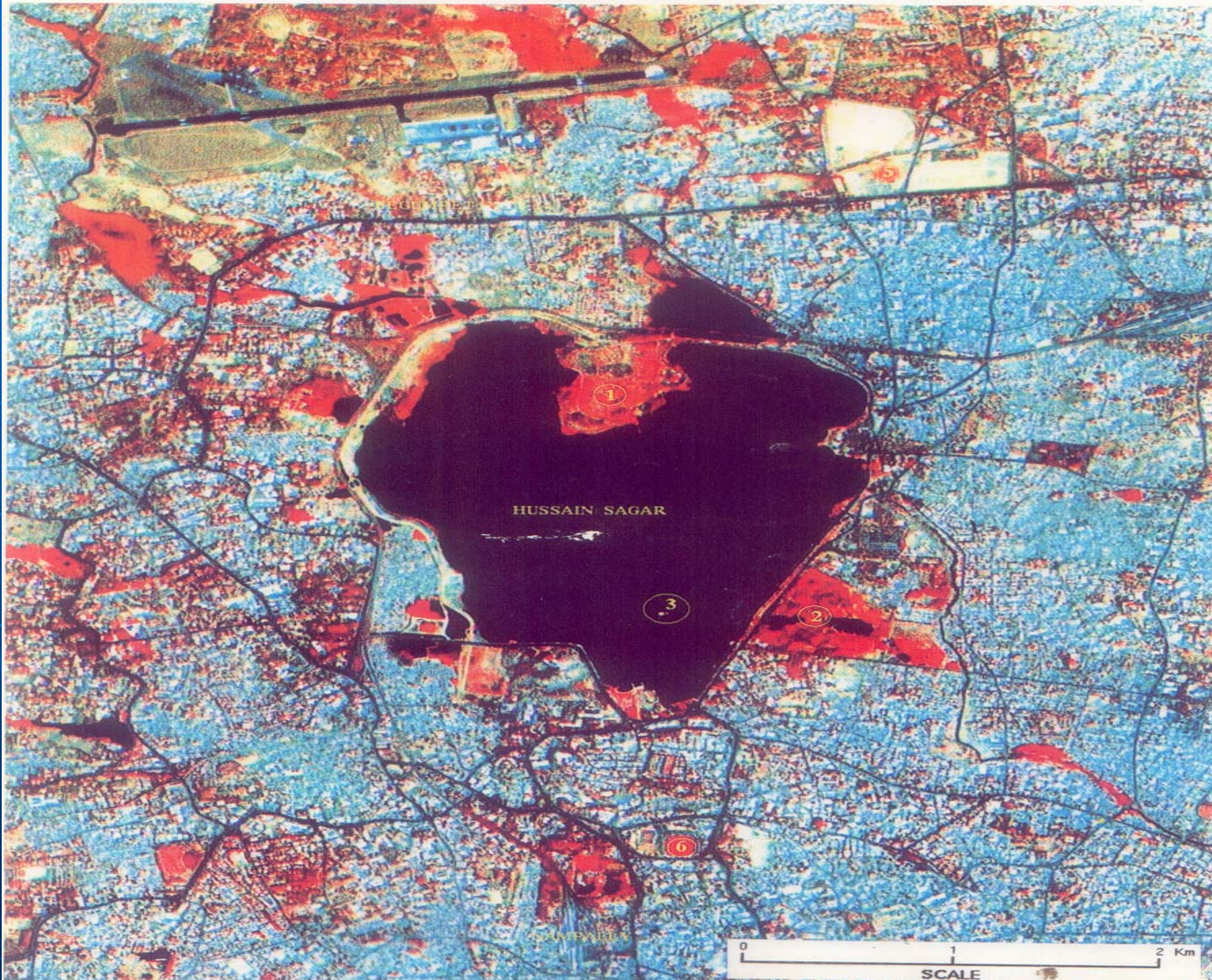
World Health Organization (W.H.O) Standards for Drinking Water

Characteristics	Acceptable	Allowable
pH	7.0 – 8.5	6.5
Total Solids	500	1000
Calcium	75	200
Magnesium	50	150
Copper	1.0	1.5
Zinc	5.0	15
Chlorides	200	600
Sulphates	200	400
Phenolic Substances	0.001	0.002
Fluorides	1.0	1.5
Nitrates	45	45
Arsenic	-	0.05
Mercury	-	0.001

IRS – IC SATELLITE IMAGERY:

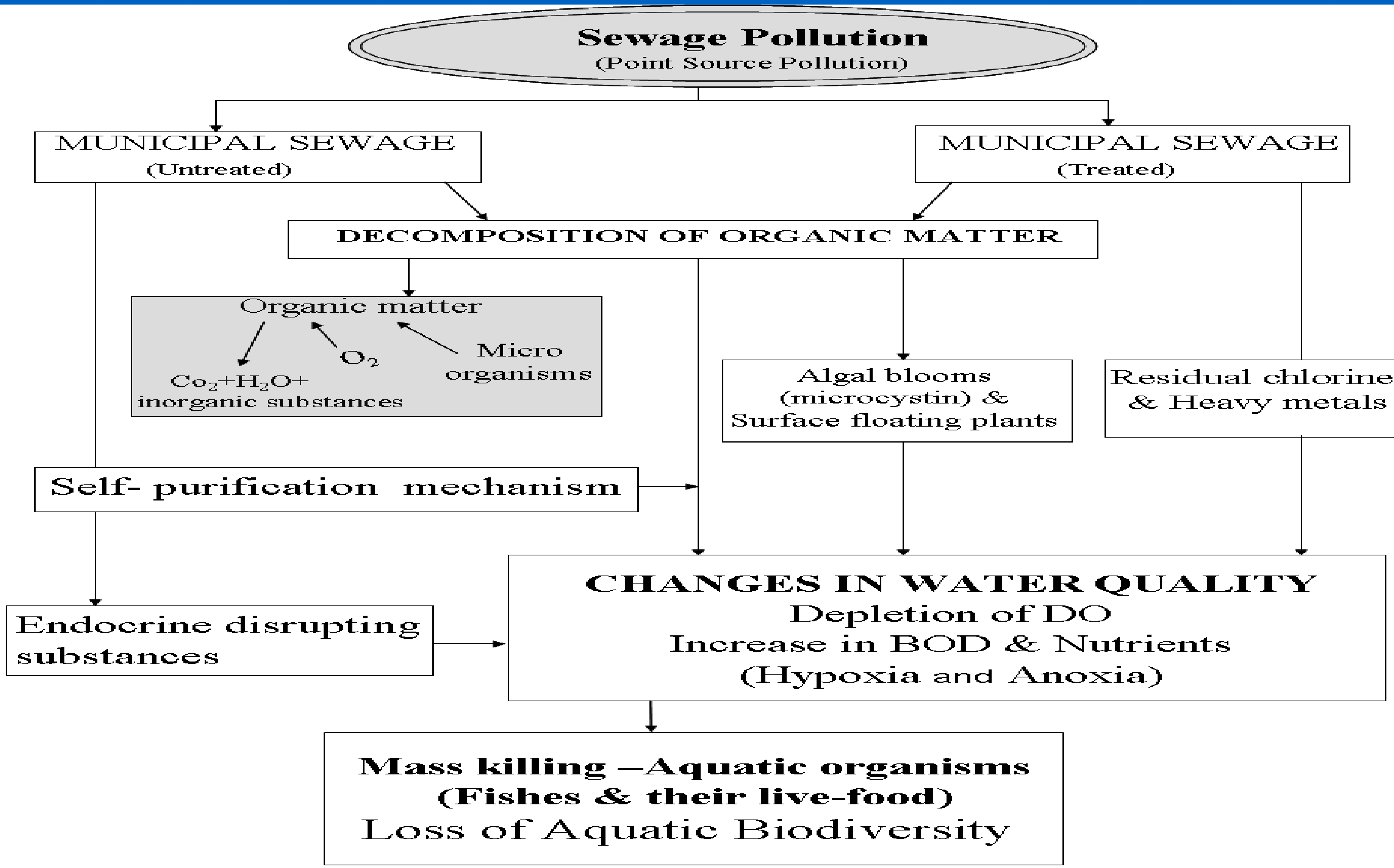
PART OF HYDERABAD SHOWING HUSSAINSAGAR LAKE

(Source: IRS – IC LISS III PAN)



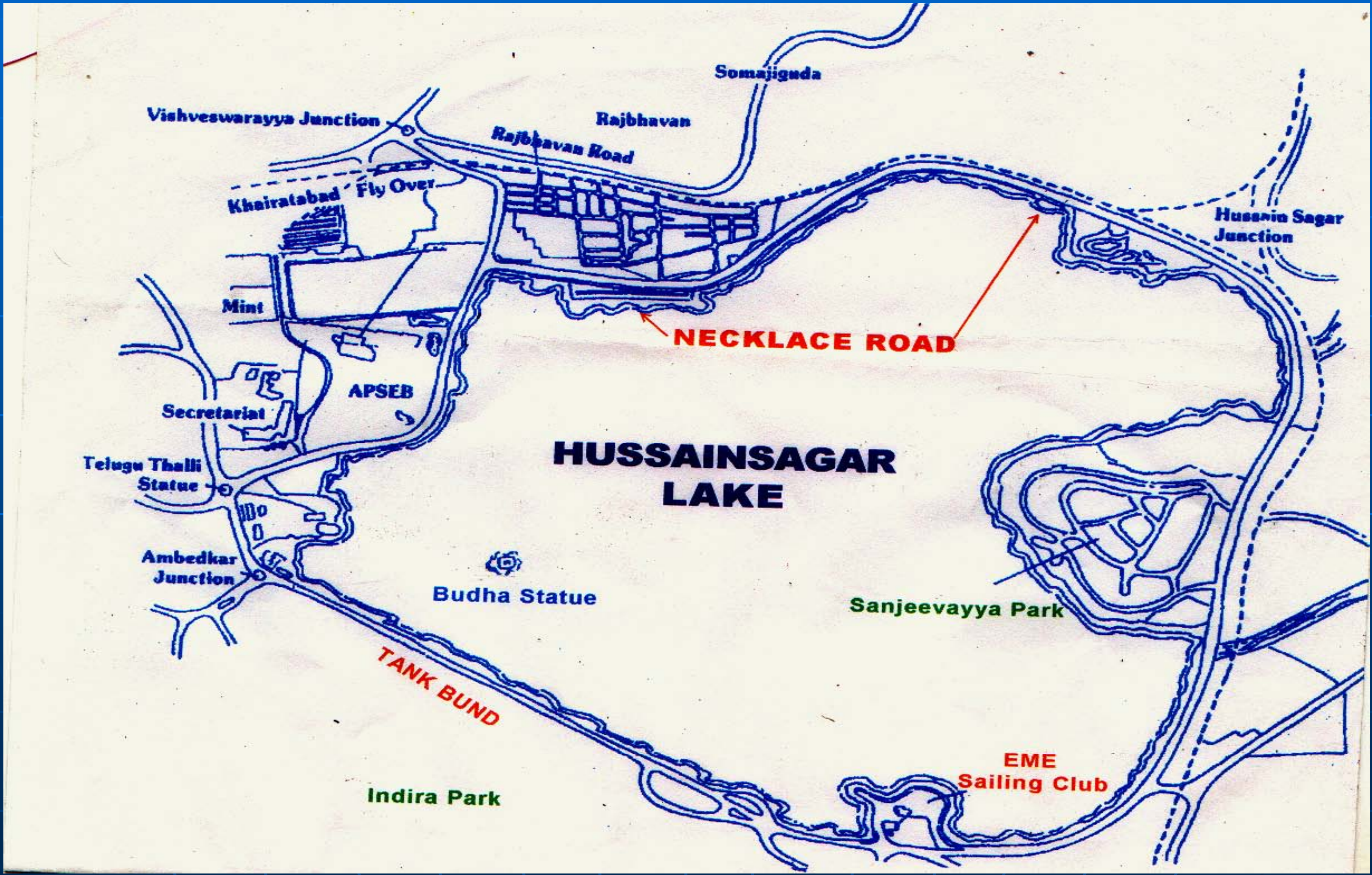
Key for Numbers on the Imagery: 1. Sanjeevayya Park, 2. Indira Park, 3. Budha Statue in the Lake, 5. Parade grounds 6. LB Stadium.

Effects of Municipal Sewage with Reference to Depletion of Dissolved Oxygen *[Kumar & Reddy, 2008]*



A haven of pollution

Schematic diagram of Husainsagar



Allochthonous Input of Pollutants: Treated Effluent [ETP]

Phytoremediation

- capable low-cost clean-up technology (with selection of a suitable plant)
- defined as the engineered use of green plants (including microbes)for deconta-minating waste-water , which remove, restrain, and render harmless various pollutants *viz* heavy metals, trace elements, organic compounds, etc.
- This technology can reduce cost, restore habitats and clean up pollution in situ or ex situ
- Water hyacinth (*E. crassipes (Mart.)) is an appropriate plant for* this purpose

Ecological & economic utilization of water hyacinth

- **Ecological –** useful as filter for solving man-made problem, water pollution-waste water treatment (though sunlight is blocked preventing O_2 exchange & altering food-web, etc.)

- **Valuable uses –** source of fertilizers for use in agricu., biological energy, making of handcraft (basket), paper and fiber boards, yarn and rope, charcoal briquetting, biogas production, etc.

“THANK YOU VERY MUCH indeed”

for your kind attention;

please feel free to discuss

PRESENT RESEARCH INTERESTS

- **Applied Soil Ecology**
  - **Belowground biodiversity – Ecosystem structure and function**
      - Earthworms [Ecology and Technology]
      - Soil-surface arthropods
      - Termites and ants
      - Soil micro-arthropods
    - Litter decomposition and nutrient cycling
    - Effects of modern Agricultural Practices
    - Effects tree plantations

- **Applied Aquatic Ecology**
  - **Water Pollution –**
    - Effects of Sewage in Urban Lakes and Canals
    - Benthic Macro-invertebrate Bio-indicators of Pollution

~~~~WATER~~~~

*"……….even that (great) '**Siva**' is the bearer of Ganga;*

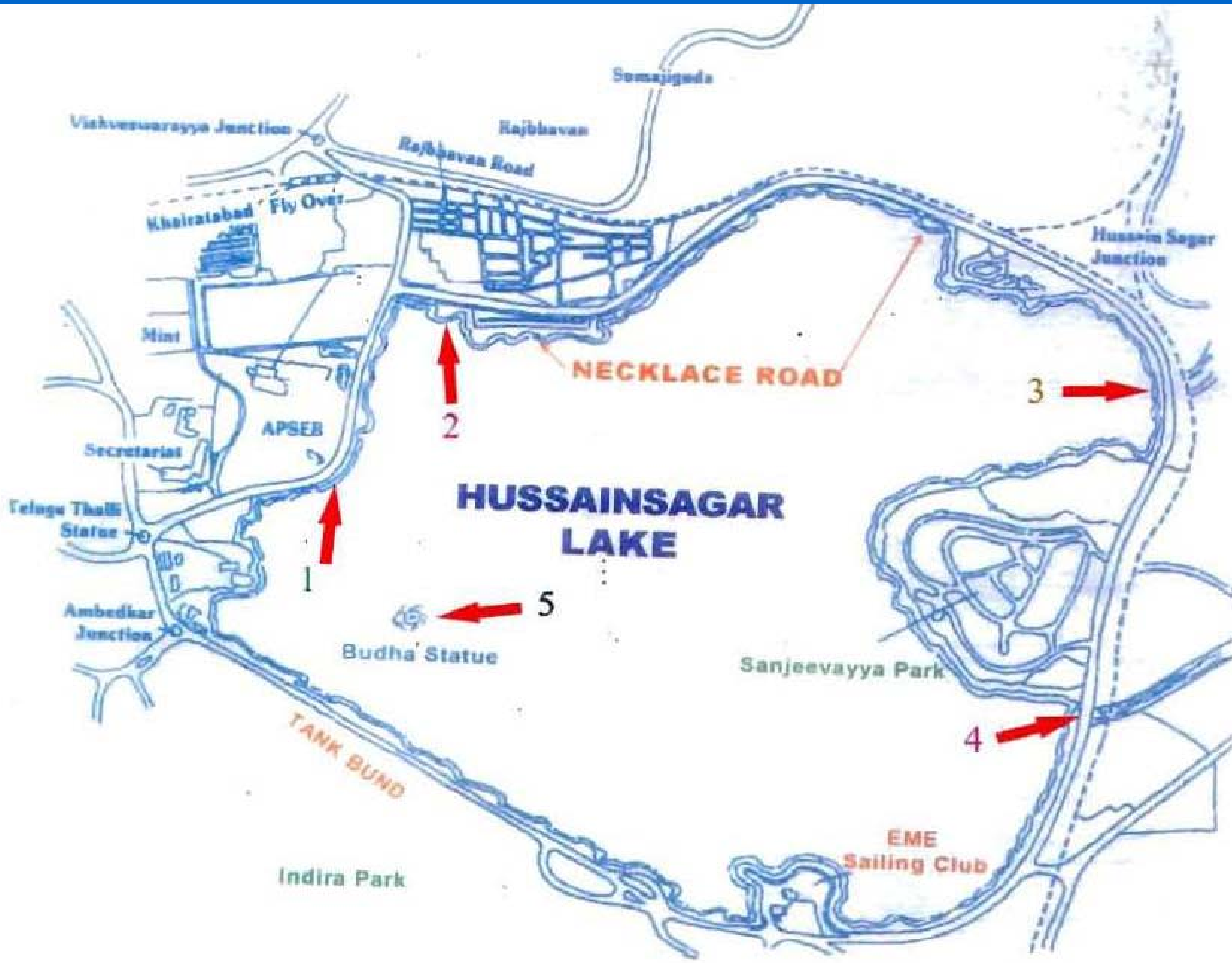
*'**Vishnu**' has the ocean for his abode;*

*'**Brahma**' has sprung from water born (lotus). Hence the water is superior to everything (else)".*

A quotation from 'Sruthi' reproduced at the porumamila inscription (1369 AD) (Cuddapab)

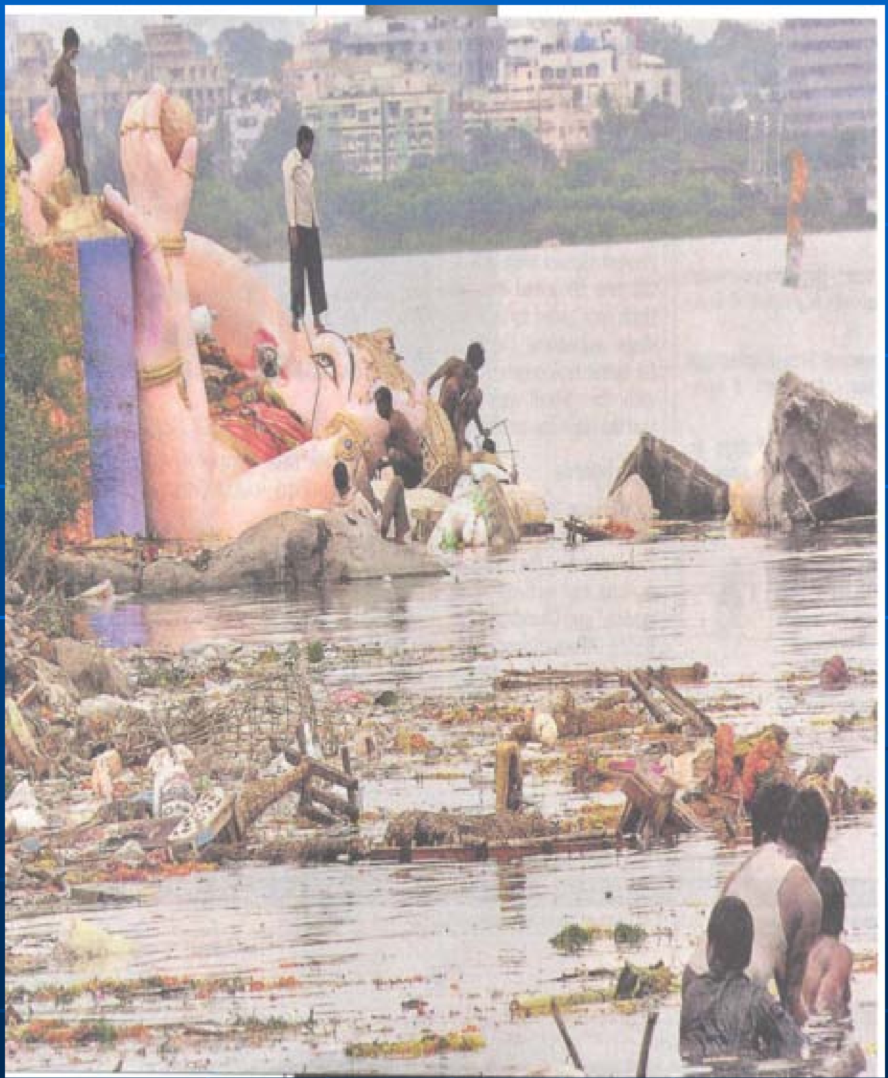
In neighboring CHINA

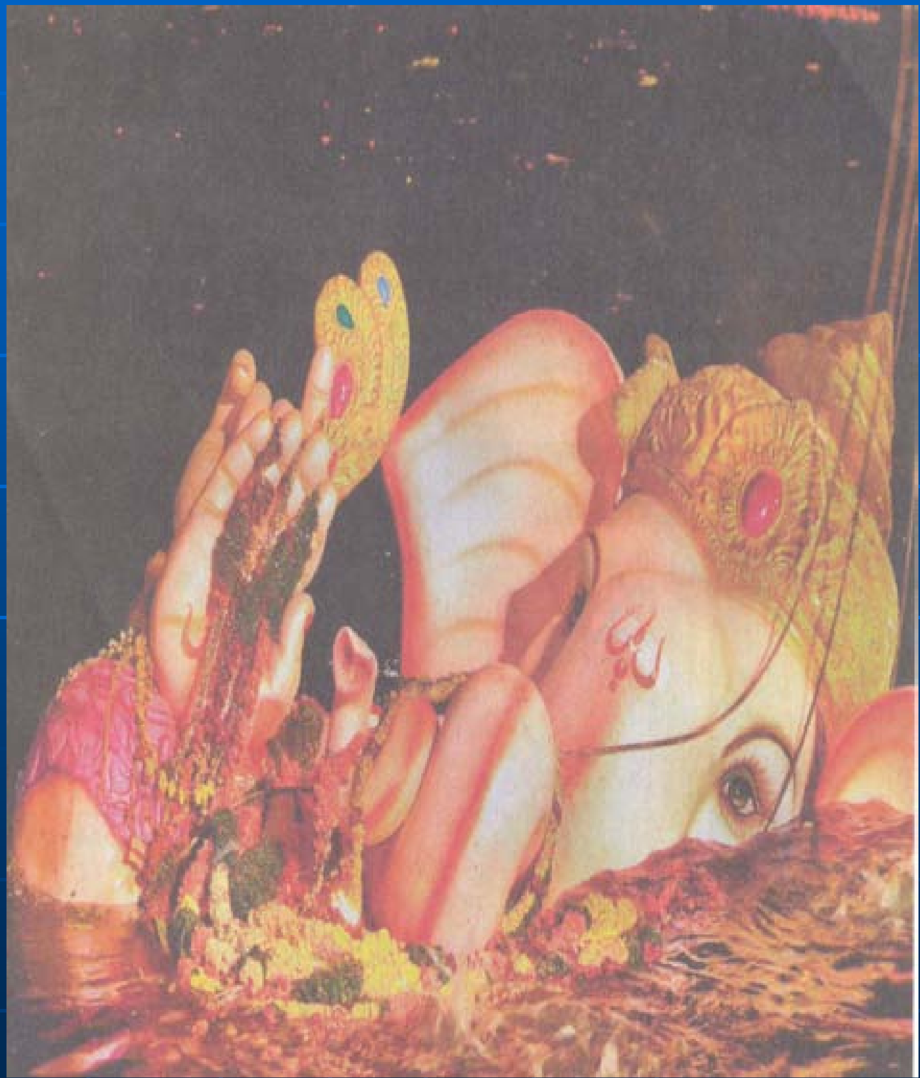
- Eutrophication is the most important environmental problem in many lakes in China at present and such lakes account for 66 per cent of which hypertrophic lakes amount to 22 per cent including the one at Nanjing – XUANWU LAKE *(XIANGCAN, 2003)*
- Because of indiscriminate discharge of various types of pollutants mainly domestic wastewater over a long period of time, the urban lakes are facing serious eutrophication, with extremely high concentration of TN, TP, Chl-*a,* low transparency and overgrown algae and aquatic weeds to various extent, and in hypertrophic level, with high concentration of BOD and COD.
- In some lakes like Lake Tajihu, the sediment is so much enriched, that these lakes can still maintain at high level of eutrophication even if all the external loading is reduced to zero.


Somajiguda
Rajbhavan
Rajbhavan Road
Khairatabad
Fly Over
Mint
APSEB
Secretariat
Ambedkar Junction
NECKLACE ROAD
2
3
HUSSAINSAGAR
LAKE
1
5
Budha Statue
Sanjeevayya Park
4
TANK BUND
EME
Sailing Club
Indira Park

Allochthonous Input of Pollutants: Municipal Raw (untreated) Sewage

'Ganesh' Idol Immersion





Change in Heavy Metal Concentrations in Husainsagar Lake after '*Ganesh*' Idol Immersion

[Reddy & Kumar, 2001]

Contaminants (mg/l)	Conc. in Water	Idol Immersion Before	Idol Immersion After	ICMR Stan.
Calcium	25.14	43.77	98.04*	75.0
Magnesium	07.78	06.59	10.02*	30.0
Arsenic	00.12	0.12	0.49	0.05
Iron	00.21	0.125	0.22**	0.3
Lead	0.289	0.351	0.45**	0.1
Mercury	0.689	0.552	0.778**	0.001
Silicon	3.537	2.054	3.826**	Not ava.

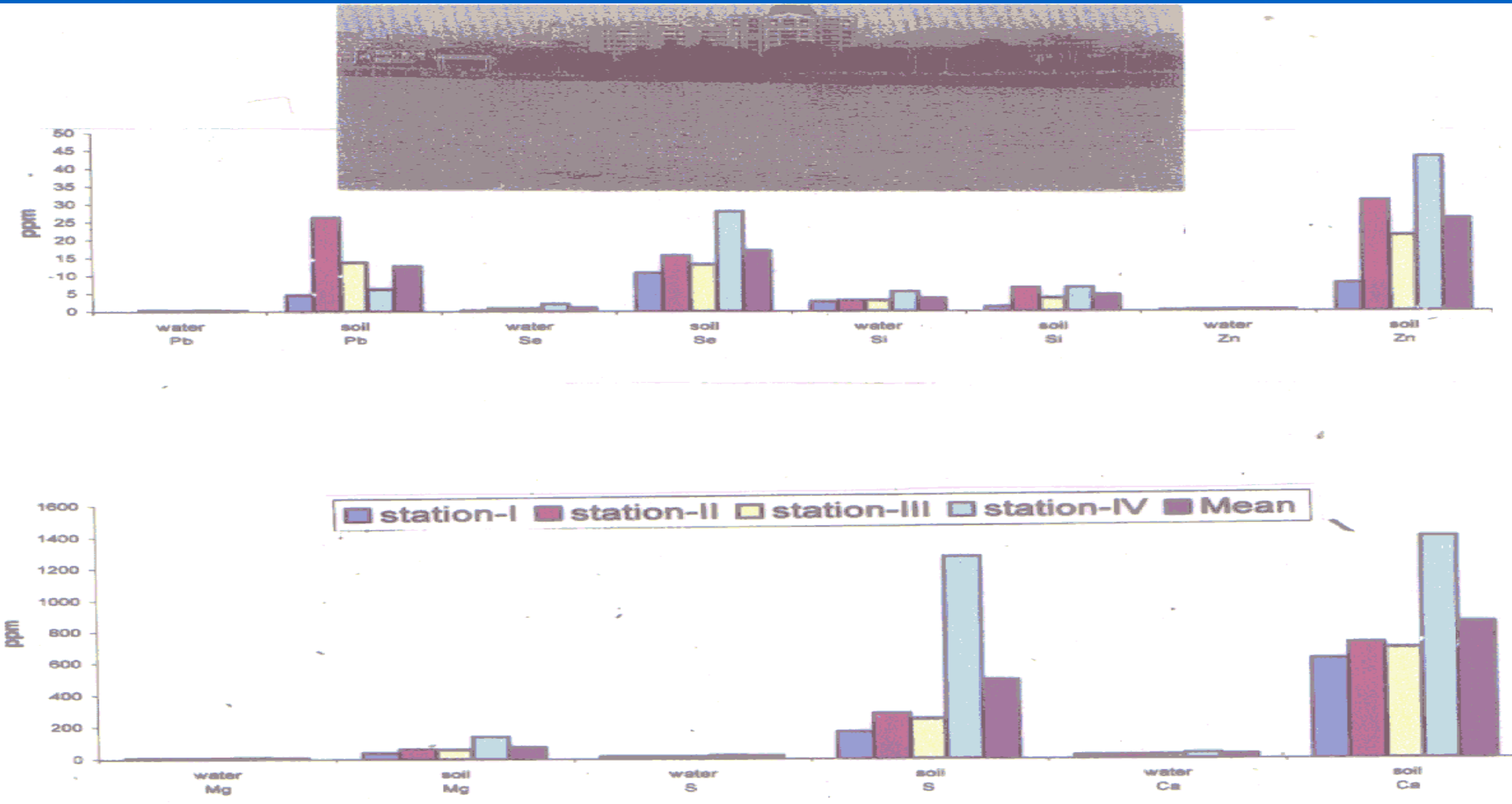
Level of Significance: *P<0.01 and **P<0.05

Disappearance of Toxic elements in Lake's surfacewater after the '*Ganesh*' Idol immersion

(Reddy and Kumar, 2003)

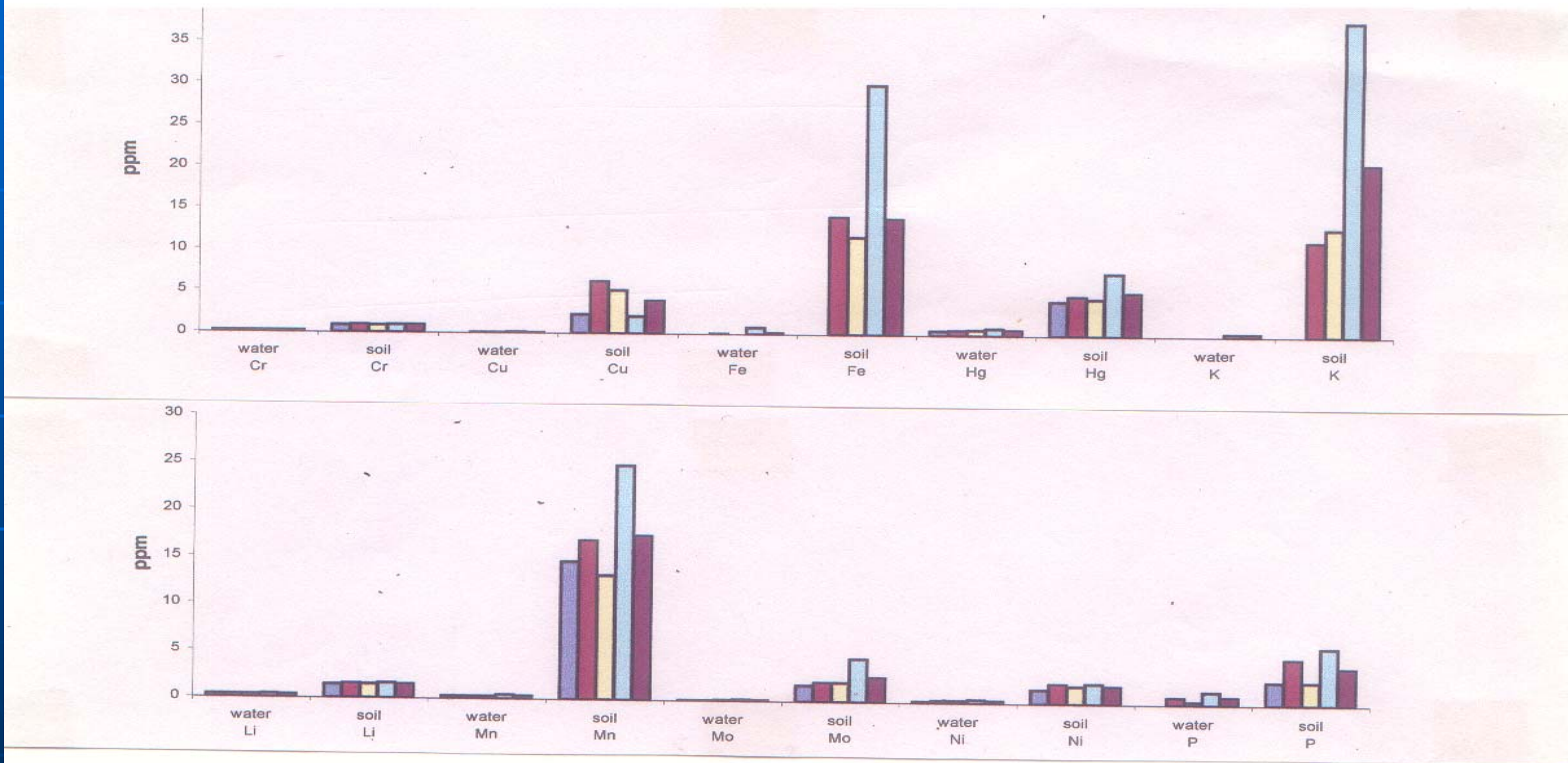
Elem (ppm)	Station – I		Station – II	
	Bef. Im	Aft. Im	Bef Im	Aft. Im
Cd	0.2656	Nil	0.2574	Nil
Cr	0.2090	Nil	0.1661	Nil
Co	0.0994	Nil	0.1150	Nil
Cu	0.0974	Nil	0.0772	Nil
B	0.2855	Nil	0.2576	Nil
Ni	0.2993	Nil	0.3072	Nil
Mn	0.3840	0.0205	0.2788	Nil
Se	0.2915	Nil	0.2551	Nil
Zn	0.3584	Nil	0.3367	Nil

Elemental concentration in surface Sediment vis-à-vis Water



Variation in concentrations of different elements (metals, nonmetals and transitional metals) in water and sediment at four stations in the littoral zone of Hussainsagar Lake

Elemental concentration in surface Sediment vis-à-vis Water



Variation in concentrations of different elements (metals, nonmetals and transitional metals) in water and sediment at four stations in the littoral zone of Hussainsagar Lake

Allochthonous Input of Pollutants: Industrial Effluents

Allochthonous Input of Pollutants: Industrial Effluents

[Reddy et al., 2008]

Elements entering through allochthonous inputs

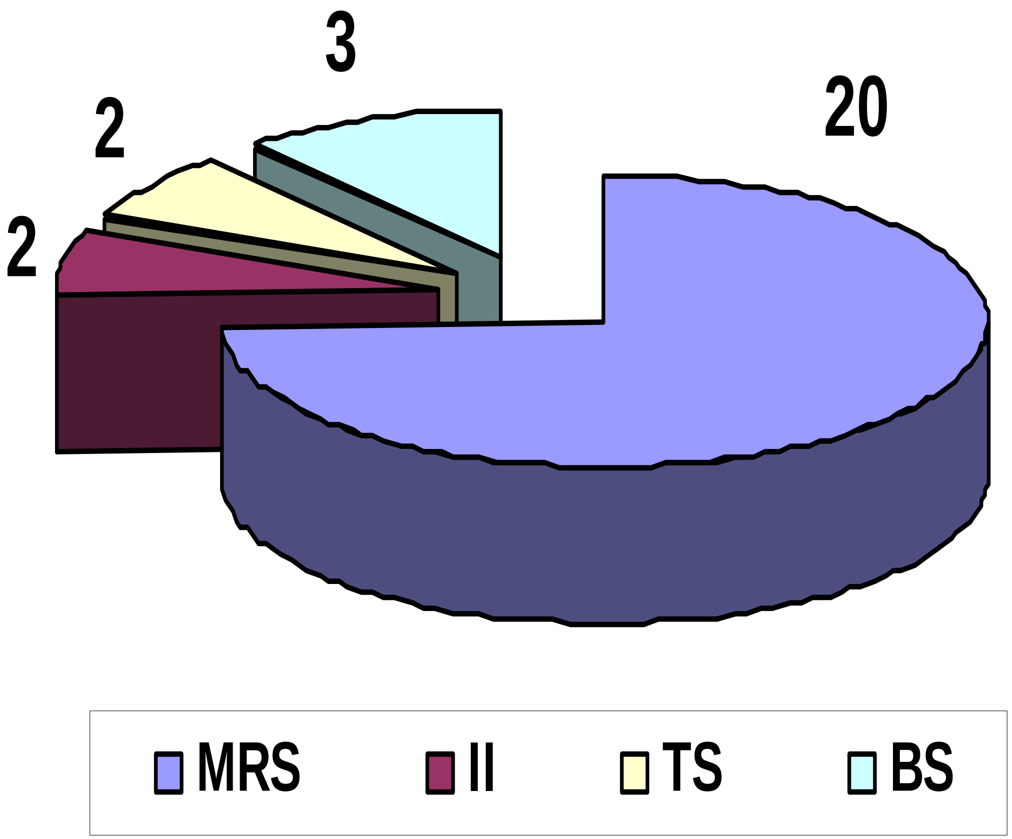


Table: Average values of Heavy metals (toxic) (ppm) in the Lake

[Site 1 = *Near NTR Marg (immersed with idols but without any type of sewage input*); Site 2 = *Treated Sewage input Channel*; Site 3 = *Untreated Raw Sewage input channel*; Site 4 = *Untreated Raw Sewage input channel with Dhobi ghat;* Site 5 = *Middle of the Lake (near Budha statue*);

SDS= CPCB Standards for Discharge of Sewage to Surface Waters; ICMR= ICMR Max. limits]

[*Reddy et al., 2008*]

Heavy metals	Site - 1	Site - 2	Site - 3	Site - 4	Site - 5	SDS mg/l	ICMR mg/l
As	0.0104	0.0059	0.0142	0.00510	0.0053	0.2	0.05
Cd	0.0049	0.0048	0.0111	0.00480	0.0044	2.0	0.01
Pb	0.1050	0.1058	0.0780	0.09461	0.2610	0.1	0.1
Se	0.0205	0.0146	0.0254	0.01751	0.0197	0.05	0.05

Table: Average values of Heavy metals (PTEs*) (ppm) in the Lake

[Site 1 = *Near NTR Marg (immersed with idols but without any type of sewage input)*; Site 2 = *Treated Sewage input Channel*; Site 3 = *Untreated Raw Sewage input channel*; Site 4 = *Untreated Raw Sewage input channel with Dhobi ghat;* Site 5 = *Middle of the Lake (near Budha statue)*;
SDS= CPCB Standards for Discharge of Sewage to Surface Waters; ICMR= ICMR Max. limits]

[Reddy et al., 2008]

Heavy metals	Site - 1	Site - 2	Site - 3	Site - 4	Site - 5	SDS mg/l	ICMR mg/l
Cu*	0.2102	0.2851	0.2119	0.2369	0.21399	3.0	0.05
Ni*	0.3742	0.0996	0.4597	0.0815	0.09569	3.0	0.02
Mn*	0.3071	0.2081	0.428	0.263	0.27492	2.0	0.1
Zn*	0.4095	0.3384	0.3134	0.2855	0.23649	5.0	5.0
Fe	0.7512	0.9234	1.1727	0.8564	0.6928	3.0	0.3
Ba	0.1160	0.1063	0.1136	0.1191	0.11409	NA	0.3
Al	2.3190	2.7299	2.4351	2.1635	8.18734	NA	0.2

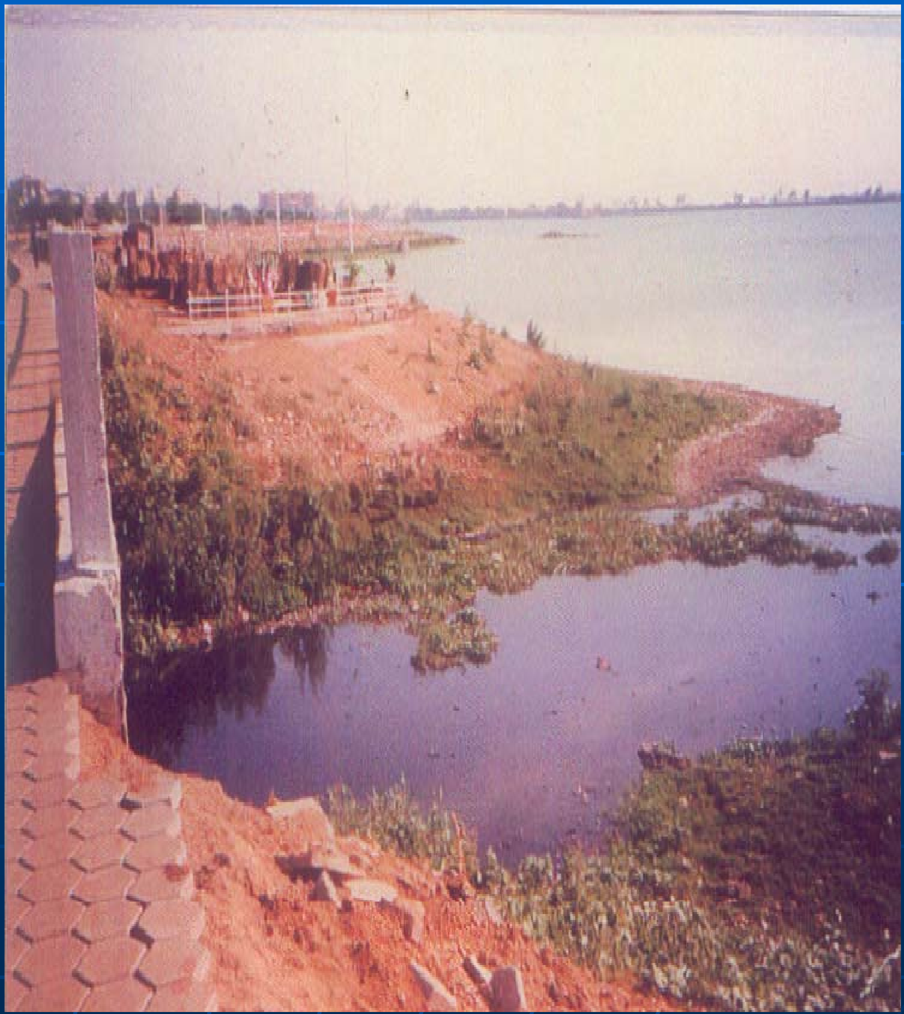
Table: Average values of other elements (ppm) in the Lake

[Site 1 = *Near NTR Marg (immersed with idols but without any type of sewage input)*; Site 2 = *Treated Sewage input Channel*; Site 3 = *Untreated Raw Sewage input channel*; Site 4 = *Untreated Raw Sewage input channel with Dhobi ghat;* Site 5 = *Middle of the Lake (near Budha statue)*;

SDS= CPCB Standards for Discharge of Sewage to Surface Waters; ICMR= ICMR Max. limits] *[Reddy et al., 2008]*

Elem-ents	Site - 1	Site - 2	Site - 3	Site - 4	Site - 5	SDS mg/l	ICMR mg/l
Al	2.31901	2.72987	2.43503	2.16352	8.18734	0.2	NA
Ca	119.83	97.579	113.06	114.88	111.49	75	NA
Mg	34.2138	29.9057	37.7254	35.2708	33.6831	30	NA
Na	213.055	176.695	240.564	205.807	201.198	200	NA
V	0.01236	0.01282	0.01371	0.01097	0.01052	NA	0.2
K	25.294	23.8676	30.9234	25.059	24.811	NA	NA
B	1.11837	0.81345	0.90198	1.149136	0.73944	NA	NA

A physical barrier preventing allochthonous inputs *(Reddy & Kumar, 2005)*



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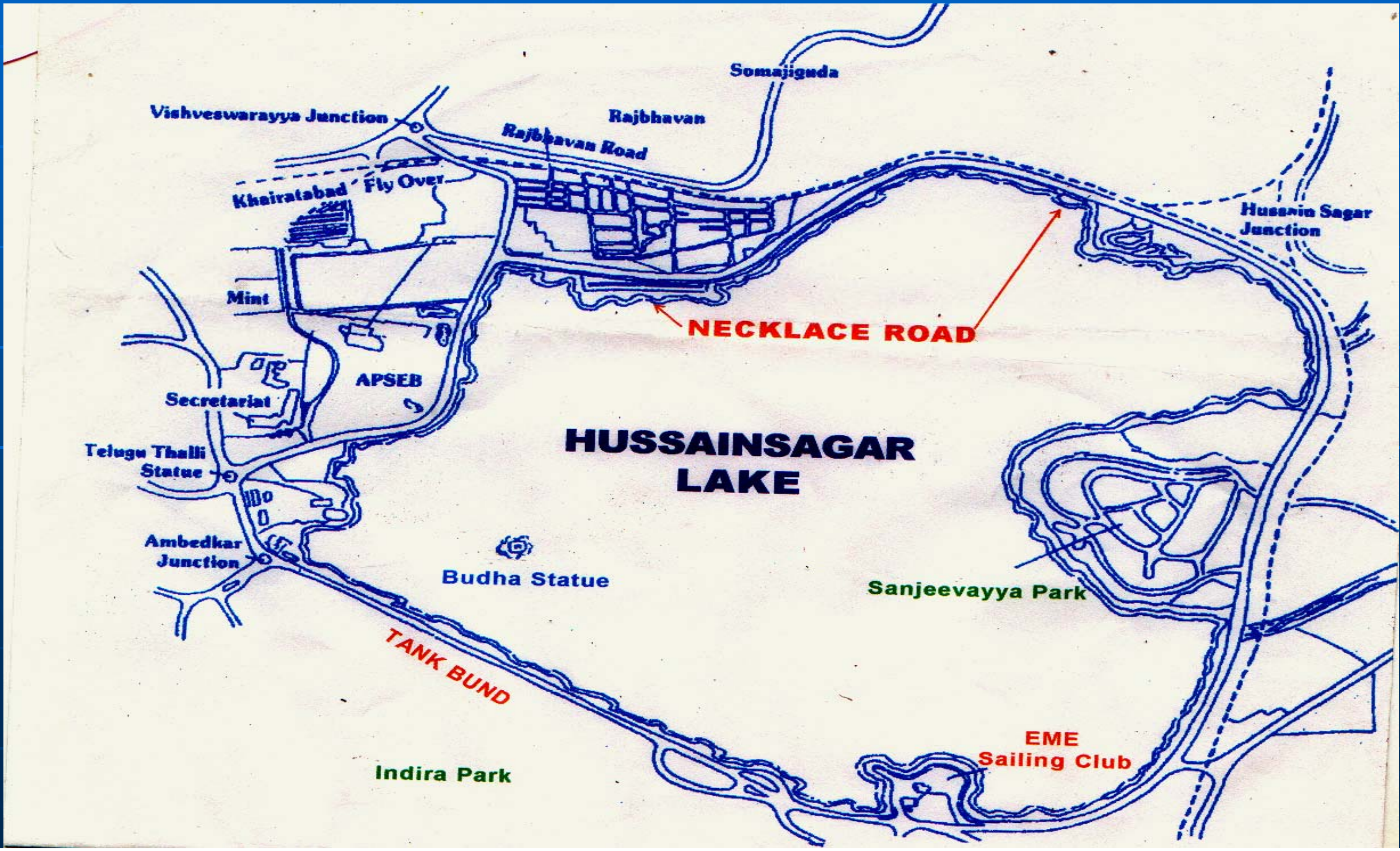

Table: Percentage reduction of heavy metals and other elements in inflowing treated sewage compared to that of the untreated sewage

[Reddy et al., 2008]

Heavy metals	Percentage	Heavy metals	Percentage	Cations	Percentage
As	58.5	Rb	02.6	Na	26.7
Cd	56.3	Sr	12.7	Mg	20.7
Se	42.6	Ba	06.4	Ca	13.7
Cr	06.6	Fe	21.2	K	22.8
Ni	78.3	Mn	51.4	B	09.8
Co	20.2	V	06.5		
Mo	11.3	Li	61.8		

Annual mean values of D.O. & B. O. D. of the lake water across the seasons

[*ANOVA: before and after the construction of a physical barrier – the necklace road*] [*P>0.05]

(Reddy & Kumar 2005)

Main Parameters	1990-1991	1999-2000	Means of Sq.	F value
D.O. *(mg/l)*	1.67	3.95	176.20	72.65 *
BOD *(mg/l)*	64.38	16.33	78508.96	229.64*

Curbing the external loading of nutrients

- **Diverting and preventing the inflow of raw untreated MS into the lake constructing a physical barrier - the necklace road and also releasing the treated effluents into the lake increased the D.O. and decreased the B.O.D. of the lake water significantly (particularly at the MRS input site, causing anoxic conditions prior to preventing the inflow of MS).**

- **The bio-indicators of sewage pollution particularly the biodiversity of benthic macro-invertebrates, *viz.*, – annelids (*Limnodrillus* sp.), diptera larvae and pupae, (*Psychoda* L., *Chironomus* sp., *Tabanus* L., *Limnophora* R & D and *Eristalis tenax*) prevalent in the lake prior to curbing of the input of MRS, has disappeared, indicating amelioration in water quality**

[Reddy and Kumar 2005]

Curbing Allochthonous Input into the Lake

- Attempts to curve and divert the inflow allochthonous inputs of nutrients and other pollutants (Municipal sewage, both raw and treated, dumping garbage), banning cloth washing that adds phosphorus to the lake water, people defecating on the banks,
- Such preventing the external loading of nutrients, ameliorated the water quality of the Hussainsagar Lake, and also of various other Indian lakes *viz.,* Dal Lake (Kashmir), Pitchola (Rajasthan), Lower and upper Lakes in Bhopal (MP) and Ooty lake (Tamil Nadu)

(Reddy & Kumar 2005)

Global Environmental Monitoring System [GEMS]

The UN Conference on the Human Environment held at Stockholm in 1972, had recommended to set up GEMS designed to provide the world' nations with information they needed on the state of their Environment, with headquarters at UNEP, Nairobi, and has the following goals:

A). An expanded human-health monitoring system,

B). Assessment of global air pollution and its impact on climate, C). Assessment of critical environmental problems relating to agricultural and to land and water use,

D). Assessment of the state of ocean pollution and its impact, E). Assessment of the extent and distribution of contaminants in biological systems particularly food-chains, F). Assessment of the response of terrestrial ecosystems to pressures exerted on the environment, G). An improved international system for monitoring the factors leading to disasters and an efficient warning system.

Monitoring Water Quality

Efforts to protect the human health, and manage the aquatic resources would not be fruitful without meaningful monitoring of water quality.

It can be of three types:

i). Physical monitoring,

ii). Chemical monitoring, and

iii). Biological monitoring

GLOBAL WATER PATTERN

- Of the world's total freshwater that comprise four percent of total global water resource:

  1. Agricultural Use 75%
  2. Industrial Use 20%
  3. Domestic Use 05%

- The degradation of water quality (or water pollution) depends on the use pattern

What is water quality monitoring?

‘Environmental Monitoring’ [including Water] - is the systematic and repetitive collection and analysis of data of different components of (water) environment which can be used – i) to help determine the quality of the environment or conditions of natural resources, and ii) to help relate environmental quality or natural resources to the factors which cause them to change or to the effects produced by such change.

Monitoring Aquatic Environment

It is a combination of different techniques with the help of which information in the form of data is collected on aquatic environments, in one of the following ways:

1. at the ground, either from fixed stations or by mobile team of observers
2. from the space, using visual images and information supplied by orbiting satellites

Instruments used for water quality monitoring

- pH meter (digital),
- Conductivity meter (digital),
- Turbidity meter (digital),
- BOD incubator,
- COD assembly,
- Flame photometer ,
- Atomic Absorption spectrophotometer
- ICPOES
- HPLC,
- Auto-analyzer
- Mercury analyzer

ICMR Standards for Drinking Water

Characteristics	HDL	MPL
pH	7 - 8.5	6.5 – 9.2
Dissolved Solids (mg/l)	500	1500
Calcium (Ca) (mg/l)	75	200
Copper (Cu) (mg/l)	0.05	1.5
Manganese (Mn) (mg/l)	0.1	1.5
Iron (Fe) (mg/l)	0.3	1.0
Chlorides (mg/l)	200	1000
Sulphates (mg/l)	200	400
Nitrates (mg/l)	20	50
Fluorides (mg/l)	1.0	1.5
Mercury (mg/l)	-	0.001
Cadmium (mg/l)	-	0.01
Arsenic (mg/l)	-	0.05
Lead (mg/l)	-	0.1

Water Pollution: Definition & types

"Water Pollution is an undesirable change in the physical, chemical or bio-logical character-istics of water that may or will harmfully affect human life or that of desirable species"

Sources: 1. Agriculture (Sedimentation, Agrochemicals, Animal waste & runoff) and

2. Urban - municipal sewage, dust, dirt & storm water contaminants, nutrients & leacheates from refuse dumps; industries – effluents of organic, inorganic and mining industries & heat); Transportation – Oil spillage & raw sewage & other waste from ships & boats