Anthropogenic impact especially from agricultural lands on water quality of the Bhoj wetland, MP"

Summary Report
of the
Work Done On
Bhoj Wetland

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INTRODUCTION

Wetlands have assumed a considerable significance in recent years with the growing interest in them for supplementing human dietary requirements and their ecological significance in terms of flood control, water purification, aquatic productivity, micro climate regulation and habits of fish and wildlife. In recent years there has been a growing awareness regarding the conservation and management of wetlands. Various investigations have been initiated to study their water quality, pollution problems, biological diversity and the economic importance as fishing habitats. However, the problems arising out of the usage of synthetic pesticides, herbicides and fertilizers in the catchments area of water bodies has not so far been addressed to.

The watershed area of a water body plays an important role in defining its trophic structure. The watershed approach to the development of aquatic ecosystems appears very promising as it has the holistic nature with the component of conservation and management of the prevailing ecosystems. The total catchment management involves the coordinated use and management of land, water, vegetation and other physical resources and activities within a catchment to ensure minimal degradation and minimum impact on water yield and on other features of environment.

The human interference in the watershed area of a water body leaves a marked influence on its metabolism. Opening of the terrestrial ecosystem may be one of the important causes responsible for the shrinkage of wetland area having geological dip towards its basin. As such, watershed plays an important role in developing natural linkages between terrestrial and aquatic ecosystems which finally controls the bio-geochemical cycles and metabolic activity of the water body. Any disturbance in this linkage will result in numerous changes in the water quality and bio-activity. Thus the eco-balance of the system gets disturbed and invites attention to strike a balance between the catchment and the water body (cf. Wanganeo, 1994 - 95).

The excessive fertilization (eutrophication) of natural waters is one of the most significant causes of water quality deterioration. This increasing eutrophication, resulting principally from the cultural activities of man, is occurring because of the excessive input of aquatic plant nutrients into water bodies. Some water bodies are naturally eutrophic in that they receive sufficient supplies of aquatic plant nutrients, mainly phosphorous and nitrogen, from natural sources to produce excessive growths of algae and macrophytes. However, many of man's activities which accelerate this transport of aquatic plant nutrients into water bodies can greatly accelerate the eutrophication process.

Phosphorous inputs to water bodies are from point sources such as domestic waste water. By contrast, large inputs of nitrogen are frequently from non-point (diffuse) sources such as agricultural runoff, precipitation, dry fallout and nitrogen fixation. These diffuse sources are usually more difficult to control.

Eutrophication control is frequently based on limiting aquatic plant nutrient inputs, usually phosphorous. Attempting to control the eutrophication process by controlling phosphorous inputs to natural waters is both technically sound and economically feasible for many water bodies. However, such a strategy requires that the relationships between the phosphorous inputs and trophic responses of the aquatic plant population of a given water body be understood on a quantitative basis.

It has not been possible in the past to quantitatively relate the phosphorous loading of a given water body to the resultant aquatic plant related trophic response, as reflected in its relative degree of eutrophication. Consequently, the management of water systems subjected to cultural eutrophication has been largely subjective.

Among the 15 to 20 elements commonly needed for the growth of aquatic plants, phosphorous and nitrogen occupies the significant position. It has been found that aquatic plants have a certain demand for nutrients, for their growth and reproduction, in proportion to the quantities of the nutrients in their cells. When one or more of these nutrients is present in short supply relatively to the others, then the overall primary productivity of the aquatic plant population will be limited by the rates of supply of these nutrients. Thus, a "demand: supply" ratio can reveal the nutrient most likely to limit productivity. The higher this demand: supply ratio, the more likely a particular nutrient will limit growth.

Although nutrient loading and nutrient concentration are related however, nutrient loading to a water body is more easily managed than the nutrient concentration within a water body.
This was responsible for developing the concept of nutrient loading and understanding the effects of agricultural and urban drainage and wastewaters on the fertility of the water bodies.

Water bodies receiving greatest quantities of nutrients especially "N" and "P" from their respective opened up catchment areas experienced the most frequent and most severe autotrophic blooms.

Geology:

The study area is a part of Vindhyan ranges and is located in the fringes of Malwa plateau. The main exposed geological formations are upper Bhander sand stone and Deccan trap lava flows. Sand stone mainly consists of brown to pink colour and orthoquastsites in nature. The orthoquastsites are predominantly composed of quartz. The sand stone formation is almost horizontal and shows occasional ripple marks and cross bedding as primary sedimentary structures. The Deccan Traps occupy the valleys between Vindhya ridges. Lava flows are almost horizontal and shows well developed spheroidal weathering and columnar joints. Black cotton soil is most common and occurs over trap areas as well as in the valleys.

Meteorological Observations:

The study area has a dry climate except in the south- west monsoon season.

March ---- Mid June	=	Summer
Mid June ---- September	=	Monsoon
Mid September---- October	=	Post monsoon
November – February	=	Winter

The average rainfall is 1240.6 mm. About 92% of the annual rainfall is received during the monsoon months, i.e., between June to September. During the monsoon the relative humidity is usually above 70%. Rest of the year air is generally dry and the relative humidity is less than 20%.

STUDY SITE:

Bhopal, the city of lakes is surrounded by low hills situated at an altitude of 550 m.a.s.l.

Bhoj wetland comprising of Upper and lower lake of Bhopal (the capital city of Madhya Pradesh) are located adjacent in the heart of the city and divides the city into two parts i.e. old and new Bhopal. Upper lake was constructed by Raja Bhoj in the 11th century AD by constructing an earthen dam across river Kolans, while Chotta Tal (Lower lake) part of Bhoj wet land was constructed a century ago by Chotta khan by putting a dam across the exit nallah (previously, Kolans River) from upper lake.

Since the conception of the upper lake the people around the water body utilized it mainly for potable purpose. The first regular water supply scheme was implemented in 1876 by a Scottish engineer, David Cook. A stream driven pumping station at Yatch Club was installed for pumping the lake water into a reservoir at Shyamala Hills and a pipeline net work was laid for the distribution of water. In 1888, the two lakes were connected by an aqueduct for admitting and controlling the flow and regulation of water supply to the city. This water soon became insufficient to cater to the growing population of the capital by the time of Sultan Jahan Begum (1901 - 1926). Thus two more stations where installed at Upper lake one to pump water to Ahmedabad and other one at Karbala with a reservoir at Idgah hills to supply to Imami gate and adjacent parts of shahjahanabad. All these pumping stations were operated by steam driven pumps which were later replaced by electric driven pumps in 1924-25. Till 1947 the city supply for the entire 1.4 lakh population of Bhopal (4.7 MGD) was not filtered. In 1958 two new townships Tatya Tope nagar and BHEL came into being and two new pumping stations of 5 MGD and 12 MGD were established with the reservoirs and treated plants at Laximinagar hills. In 1973, one more 2MGD-treatment plant was built at Shyamala hills with pumping stations at Yatch club. The present population of Bhopal has increased more than ten fold during the 43 years and is presently being supplied about 32 MGD of water. The excessive requirement has been met from the other water resource viz., Kerwa (1986) and Kolar (1989). Till 1947, the city water was not filtered. In 1956 Bhopal became the capital of the new Madhya Pradesh. At that time in order to meet the requirement of the potable water two pumping stations of 5 MGD and 12 MGD were constructed near Kamla Park. In 1963 the water storage capacity of the Upper lake was raised from 1359 MC to 3588 MC ft. by installing 11 radial gates of 12 ft height called as Bhadbhada weir}.

Upper lake though mainly used for drinking water is also used for fishing, swimming, boating and water sports etc. This water body has great importance due to its historical, socio-economical, ecological and scenic values. The lake is shallow and infested by thick growth of macrophytes.

Under management program numbers of works have been carried out in Bhoj wet land by EPCO with the financial help from overseas Japanese bank in order to answer various types of problems. However, the problems arising out of agricultural practices and the changing land use land cover have not been answered till date

Bhoj wetland the present study site was identified as Ramsar site during the year 1995. It is situated approximately 5 Km away from the main Bhopal city Railway station, at an altitude of 490 m.a.s.l and lies within geographical coordinates of 23^{o}10' – 23^{o} 20' N and 77^{o}15' – 77^{o} 25' E (Wanganeo, 1994-95).

Upper Lake covers an area of about 38 sq km. The lake is East – West elongated with irregular margins. The early old city was developed on its eastern and partly northern banks. The sequence of growth highlights development towards southern periphery. Gradually over a period of time the raw sewage of the nearby slums and other residential areas found its way into the lake through various sewage channels and drains. Also fertilizer and pesticide residue found their way into the lake from this side of the lake. On the western bank, the land is used for agricultural practices using available moisture.

Besides, being one of the chief sources of potable water this ecosystem is providing tremendous benefit to its local habitants through fish production and economically and commercially viable plants. Further, it provides a critical habitat for water flow and other birds as well as for countless mammals, reptiles, amphibians and invertebrate species. It was during 1010 -53 A.D a reservoir presently called as Bhoj wetland was constructed by Parmar King Bhoj of Dhar by installing an earthen dam (presently called as Kamla Park) adjacent to a tank, fed by a river (joined by number of streams) presently called as Kolans nadi in order to supply pure water to the inhabitants living in Bhopal township (Rathore, 1988). Ali (1981) reported that the lake recorded an area of 6.4 sq km during the year 1819-1837. Water supply from this water body was not adequate to meet the growing demand of drinking water as such, it was considered to increase the capacity by installing radial gates 150^o down the old stone masonry spillway at Bhadbhada in the year 1963.

Catchment area of Upper lake, most of which drains into Kolans river, is 361 km^2 and spreads up to Sehore district. Wanganeo (1995) divided the whole catchment area of lake into eleven sub watersheds (based on their drainage pattern) for the micro level analysis (Fig.1). Watershed numbers I, II, III & XI are of urban nature. Watershed No's IV, V & X are representing countryside, while watershed No's VI, VII, VIII and IX come under rural areas. The watershed No. VI is the largest in area (255.912 km^2) and basically it is agricultural in nature.

So the catchment area activities of upper lake may be divided in three sectors namely the urban, semi urban and rural. As per the topography of the catchment area, the north side of the lake is having major thrust of urban and semi urban activities which contribute the solid and liquid waste.

There are twenty two defined nallas in eleven water sheds (Table 1 and Fig.2) bringing in sizeable amount of sludge, silt, agricultural residue etc. The land-use / land cover changes in these watersheds have been recorded in Table 2 and Fig's 3, 4 & 5).

Table 1. Input nallah's from the catchment area of Bhoj wetland

Location of Nallah	Average in flow In MLD	Catchment area of Nallah in Sq. Km	Type of inflow observed
Halalpur	2.95	0.7863	Domestic Waste Water, Silt, Sewage
Khanugaon	2.4	0.866	Sewage and Silt
Ahmedabad	5.09	0.747	Sewage and Soil waste
Karbala Nallah	3.08	0.617	Sewage, idol immersion
Fateh garh	0.90	0.193	Sewage and Solid waste
Seedighat(Badal Mahal)	0.77	0.153	Sewage and Solid waste
Sheetaldas Ka Bagicha	0.45	0.0798	Sewage and Idol immersion
Boipura near Bharat Bhavan	0.90	0.1914	Waste water
Dharampuri	0.45	1.428	Silt
Aamkherda near well	0.90	0.632	Silt
Aamkherda main	1.36	1.000	Silt
S.A.F. Bhadbhada	2.27	1.621	Sewage, silt and agricultural waste
Kotra Sultanabad	4.54	2.379	Sewage and silt
Gora Nallah	4.71	8.143	Silt & agricultural waste
Itkheri	2.72	303.90	-do-
Khajuri Sadak	0.90	19.662	-do-
Bhainsa Kheri	0.45	8.94	-do-
Bairagarh Kalan	0.90	4.46	-do-
Sehore Naka, Bairagarh	2.72	0.688	Sewage and solid waste
Indra Nagar,Bairagarh	2.49	0.375	Waste from slaughter house.
Bus Stand, Bairagarh	0.43	1.598	Waste from shoe factory
Laukhedi Bairagarh	3.54	2.489	Silt,agricultural residue & Sewage
		361.00	

(Source: PHE, project code : 2.2)

Table 2. Change in Land use / Land cover in different watersheds of Bhoj wetland

(Source: Wanganeo, 1998)

Watershed No.	Area km^2 1974	Classification	Percent change			Phase I	Phase II	Total % change
			84 (A)	88 (B)	94 (C)	B -A	C - B	C - A
I	1.0428	Built up land	58	59	90	1	31	32
		Crop Land	4	22	10	18	- 12	6
		Barren Rockey	38	19	-	-19	-	-
II	6.4864	Built up Land	18	21	31	3	10	13
		Croop Land	43	65	59	22	-6	16
		Decidous (open)	3	-	2	-	2	-1
		Fallow Land	23	7	-	-16	-	-
		Barren Rockey	10	7	8	-3	1	-2
		Water logged	3	-	-	-	-	-
III	5.523	Built up Land	56	66	8	-2	6	18
		Crop Land	24	24	36	0	12	12
		Fallow Land	13	9	-	-4	-	-
		Barren Rockey	5	1	-	-4	-	-
IV	8.94	Built up Land	23	16	26	-7	10	3
		Croop land	70	65	63	-5	-2	-7
		Fallow Land	7	12	11	5	-1	4
		Water Logged	-	7	-	7	-	-
V	5.265	Built up Land	3	7	8	4	1	5
		Crop land	66	75	75	9	-	9
		Fallow land	23	11	14	-12	3	-9

		Barren Rockey	6	7	3	1	-4	-3
		Water logged	2	-	-	-	-	-
VI	255.912	Built up Land	0.01	0.28	0.23	0.26	-0.04	0.218
		Crop Land	83	77.9	67.5	-5	-10.39	-15.45
		Fallow Land	14	19.5	30.8	5.5	11.27	16.79
		Barren Rockey	2.41	2.11	1.21	-0.3	-0.84	-1.154
		Water Logged	0.57	0.04	-	-0.53	-	-
		Plantation	-	0.13	0.17	-	-	-
VII	10.41	Built up Land	0.82	2.05	0.97	1.23	-1.08	0.15
		Crop Land	87	92.2	81.1	5.15	-11.09	-5.94
		Fallow Land	10	2.71	16.6	-7.29	13.93	6.64
		Barren Rockey	2	3.07	1.78	1.07	-1.29	-0.22
		Water Logged	0.18	-	-	-	-	-
VIII	2.29	Crop Land	97	79	84	-18	5	-13
		Fallow Land	3	17	13	14	-4	10
		Barren Rockey	-	4	3	4	-1	3
IX	39.91	Built up Land	0.17	0.2	0.26	0.034	0.06	0.09
		Crop Land	84	72	55	-12	-17	-29
		Fallow Land	10	22	40	12	18	-29
		Barren Land	4	5.8	3.8	1.8	-2	-0.2
		Water logged	1.83	-	-	-	-	-
X	9.075	Crop Land	91	66	60	-25	-6	-31
		Fallow Land	0	25	30	25	5	30
		Barren Land	5	9	10	4	1	5

		Water logged	4	-	-	-	-	-
XI	15.394	Built up land	18	23	35	5	12	17
		Crop land	6	-	-	-	-	-
		Deciduous(open)	68	77	65	9	-12	-3
		Fallow Land	8	-	-	-	-	-

Though area wise watershed No.1 occupies 11th position, i.e., being smallest yet human population wise it occupies first position, followed by watershed No's., 2,3 and 11. Even if watershed No.6 Occupies the maximum area of the whole catchment area, yet from the human population wise it comes in the sixth position on the basis of number of humans per sq km., likewise, based on the distribution of animal / sq km area, watershed No's., 3,4 and 9th occupy the first, second and third position, while the biggest watershed area (6th watershed) occupies the seventh position (cf. Wanganeo, 1994-95).

The Land use Land cover during a decade reveals that built-up land is increasing at a rapid speed in the watershed areas no's 1 to 5 and 11. This activity has started creeping into the rest of the watershed areas. The crop land has been considerably reduced while fallow land is increasing. Secondly, the deciduous forest cover has also started declining (cf. Wanganeo, 1998).

Total Lake area:

Table 3 records the changes in the total lake area. It has been notice that the lake area shows a considerable change during the year round study period. This change is on account of precipitation, evapo-transpiration and regular draining of water through potable water distribution system.

Table 3. Reduction in total lake area (sq. km) (Source: Wanganeo, 1998)

Season	Changes (sq. km)			5 years	5 years	10 years
	1984	1988	1994			
Pre monsoon	30.2	28.025	27.025	- 2.175	- 1.0	- 3.175
Post monsoon	33.625	36.425	30.01	2.8	-6.415	- 3.615

Geological features of eleven watersheds reveal abundance of quartz (SiO_2) followed by glauconite (iron) and niter (potassium). As such abundance of SiO_2 and iron in the present water body cannot be ruled out.

Catchment interaction:

Pronounced anthropogenic activity (viz., Agricultural, denudation of forest cover, Poultry, Animal raising, Building construction, and enhanced vehicular traffic) has resulted in the sedimentation and subsequent shallowing of the water body on account of loss of soil with surface runoff.

The incoming agricultural waste enriches the lake water with nutrients and enhances the problem of eutrophication.

The expansion of urban areas and development of slum localities in the catchment areas depletes the water quality and increases the eutrophcation problems.

Apart from the problem created by the slums, around the lake, human settlements in Bairagarh, Retghat, yatchclub, fatehgarh, the dumping grounds in the vicinity of the lake, the new colonies sprawling nearby have accentuated the pollution in this waterbody.

Soil nutrients: Soil samples of eleven watersheds revealed that available nitrogen was high (9.26 mg / 100 gm) in watershed number V and low (4.36 mg / 100 gm) in watershed number I. Watershed number II recorded high (0.87 mg / 100 gm) available phosphorous and low (0.17 mg / 100 gm) in water shed number IV. The available potassium levels in the eleven water sheds of Bhoj wet land ranged from 9.55 mg / 100 gm (water shed No. I) to 26.37 mg /100 gm (water shed number IV), Wanganeo (1994 - 95).

Hydraulic Inputs:

On annual basis maximum hydraulic input from watershed No VI (64.244 $m^3 \times 10^6$) has been recorded as most of the water is received during monsoon period On the other hand Watershed No's I, II, and XI recorded a continuous input in almost all seasons into the Bhoj wet land. This may be on account of the urban nature of these watersheds, which continuously discharge human generated waste water into the system.

Nutrient Budget of Upper Lake:

Seasonal input of various chemical constituents from eleven watersheds reveals that watershed No's II, VI and IX contribute maximum amount of chloride, calcium, magnesium, and sodium during monsoon period.

Potassium also recorded higher values in the incoming waters during monsoon period but was mostly contributed on a large scale by watershed No's VI, IX and X . Watershed No's IX and XI recoded higher contribution of iron. Maximum amount of phosphate phosphorous was contributed from watershed number VI only, while maximum Total phosphorous was contributed from watershed numbers IX and XI.

Nitrate nitrogen though present in relatively good quantity recorded highest values in the incoming waters from watershed No's VI, IX and XI .These highest values were obtained during monsoon period (Wanganeo, 1998).

Considering the input and out put of 9 major and minor nutrients on yearly average basis into Bhoj wetland it has been found that calcium and magnesium depicted maximum inflow and outflow. Calcium and magnesium recorded an inflow of 4039.31 and 1129.55 tonnes respectively.

During the same period, chloride in the system recorded 2838.5 tonnes which in turn depicted that the outgoing waters show more chloride concentration (2900.23 tonnes/year). Total phosphorous in the system estimated was 14.2 tonnes per year in comparison to its input of 31.53 and an out put of 14.795 tonnes /year (Fig.6). While computing nitrate budget of the water body, it was found that the system received a positive autochthonous input of 3.543 tones nitrate / year. For total iron, an inflow of 22.057 tonnes / year was recorded against an out flow of 15.275 tonnes / year. The ambient water during this period depicted a concentration of 15.6 tonnes /year of total iron.

Sodium recorded an input of 178.6 tonnes /year and potassium recorded an input of 334.855 tonnes / year. In put of potassium during the course of investigation was much higher than that of sodium (Wanganeo, 1998).

IRRIGATED AND FERTILIZED LANDS:

Drainage from irrigated and fertilized land usually contains significant amounts of nutrients. Around 0.5 kg/ha/yr and 2 kg/ha/yr of Phosphorous inputs from a watershed having 8 percent and 20 percent slope were recorded respectively by Eck et al. (1957). He also found that significant amounts of nitrogen were lost from both fields.

Likens et al. (1970) kept fields bare by regular application of herbicides to stimulate plowed-field conditions. They concluded that large proportions of nutrients are lost from bared earth. Midgely and dunklee (1945) found that manured field runoffs contained on the average 3 mg/l of nitrogen and 1mg/l of phosphorous. Sawyer(1947) found that agricultural drainage near Maidson, Wisconsin contributed approximately 2040 kg of nitrogen and 10 kg of phosphorous /2mile/yr. Runoff from plowed and / or fertilized fields therefore contribute significantly towards the enrichment of the receiving water body.

Forested lands lose considerably less nutrients by runoff than do agricultural lands.

Major ionic concentration at different watersheds of Bhoj wetland (Wanganeo, 1998)

(a) **Inlet waters :**. Among major anions, concentration of bicarbonate was more at watershed no 9, followed by watershed No. 10. The concentration of chloride was also recorded high at watershed no. 9 . In general the sequence of dominance of various anions is as follows:

Bicarbonate > Chloride > Sulphate > Carbonate.

Among cations, calcium was more abundant at watershed No. 6, followed by watershed No. 8 . The presence of rest of the cations was not of that significance.

The sequence of dominance of cations is as follows :

Calcium > Magnesium > Sodium > Potassium

(b) **Ambient water :** In ambient water, among major anions, concentration of bicarbonate was slightly more at surface water than at middle and bottom waters, while concentration of chloride was more at bottom waters than at surface and middle waters.

Of cations calcium was slightly high at surface and bottom waters.

The sequence of dominance of various cations is as follows :

Calcium > Magnesium > Sodium > Potassium

(c) **Outgoing waters, intake point of potable pumping water and seepage water :**

Among cations higher values of calcium, magnesium, sodium was recorded at outgoing (Bhadbhada site) waters than seepage and pumping water.

Among anions bicarbonate was also recorded to be more in outgoing water than in seepage and pumping water.

Inflow of sewage and waste water from the catchment

Unplanned development in the catchment areas and neglect of concern for the lakes are he primary cause for flow of untreated human wastes, excreta and the like into the lakes, causing severe degradation of the water quality. Overflow drains, leakage from broken sewage pipelines, etc cause the flow of sludge and sewage through 31 nallah in the Upper Lake and 28 nallahs and point sources in the Lower lake. It is estimated that 5.381 million litres of sewage flows into the Upper lake and 36627 Cu.M into Lower lake everyday. Besides, bathing, washing of clothes, cleaning and washing of vehicles also bring a large quantity of pollutants into the lake everyday (Bhoj wetland detailed project report, 1998).

POLLUTION DUE TO AGRICULTURAL ACTIVITY IN THE CATCHMENT:

Increased use of chemical fertilizers, pesticides and insecticides for the agricultural production in the catchment areas due to modern agricultural practices. The residual nutrients and agricultural waste find their way into the Upper Lake. *Trapa bispinosa* (water chestnut) is cultivated by local habitants in both Upper and Lower lakes. Fertilizers and pesticides are used indiscriminately for personal / commercial gains. This cultivation procedure enhances the process of eutrophication. Further, after harvesting the plants are allowed to sink to the bottom at the end of the season, causing further pollution.

IMMERSION OF IDOLS AND TAZIAS:

During certain festivals large number of idols, big and small made of straw, mud, plaster of paris, plastics, chemicals, soluble and insoluble paints and textiles are immersed in the lakes. Similarly Tazias made of bamboo and paper is also immersed at Karbala in Upper Lake. This activity adds approximately 70 tons of clay to the lake annually, which besides causing siltation, are likely to add heavy metals.

Lower Lake (N $23^{o}14'$ – $23^{o}16'$ and $77^{o}24'$ – $77^{o}25'$) of Bhopal is about 200 year old water body which was constructed by forming an earthen dam (presently known as Pulpukhta).
The lake receives inflow of water from the upper lake both in the form of seepage as well as from a connecting pipe besides large amount of domestic sewage of old city through several inlets. There are six major and number of small inlets carrying land drainage and sewage to a varying degree from the surrounding areas.

The lake has a total area of 1.29 sq kms. A maximum depth of 11.7 mts and a storage capacity of 8 MCM. Some important morphological characteristics of Lower Lake As reported by Bhatnagar (1982) are:

Shore line	:	6.16 km
Surface area	:	1.297 Km^2
Max. Length	:	1.615 km
Max. Width	:	0.954 km
Max. Depth	:	11.7 km
Mean Depth	:	6.16 m
Volume	:	7.997 km^3

Thassu (c.f., Bhatnagar, 1982) reported that Lower lake receives very high amounts of phosphorous and nitrogen through number of sewage inlets from surrounding areas. The maximum contribution was through the inlet near Kamla park through which sewage of upper lake was diverted. It carried total phosphate 1135.15 kg/yr and total nitrogen to the tune of 2452.80 kg/yr. and next to it was the inlet near Jahangirabad which brought sewage from a very large area and added 657 and 1292 kg. of phosphates and nitrogen respectively each year. Such addition of nutrients has resulted in the hypereutrophic condition of the lake.

The water level in the lake is maintained at a constant level by regular overflow through a waste – weir at Pul Pukhta. The exit from this lake takes the shape of a nallah and is known as Patra Nallah, which ultimately joins the river Halali.

The inputs from major nallahs are responsible for the addition of approximately 1, 40,000 gallons/ hour of raw sewage and sludge.

The out put from the lake is in the from of superfluous water above a weir (Pul Pukhta) a significant morphometric characteristics. This water is highly oxygenated (sometimes it is super saturated with dissolved oxygen) while the bottom waters are devoid of dissolved oxygen due to typical morphometric character which is responsible for its high hypolimnitic water retention/detention period leading to anoxic bottom waters.

This part of the Bhoj wetland is having mainly urban catchment area as such the inputs are mostly in the from of garbage / decomposing organic material, humus material, detergents, Ash / coal and grease/oil from the vehicles etc. from the surrounded habitation. This all incoming material is responsible for siltation and eutrophication.

The cattle population has also been found to be responsible for the addition of manure in the form of their excreta which is equally responsible for the deterioration of the trohpic status of the water bodies (Bhoj wetland).

The portion close to the incoming channel is supporting luxurious growth of macrophytes, while the open waters, highly impregnated with nutrients are now experiencing highly reduced species diversity and are over loaded with the growth of a single cyanophycean species viz., *Microcystis* sp.

Table 4. Nitrogen and Phosphorous Budget of Lower Lake

(Thassu (c.f., Bhatnagar,1982))

Station	Average flow Litx10^3 / day	Total – P kg/yr	Total – N kg/yr
Banganga	6,384	292.00	930.75
Science College MVM	4,560	346.75	1029.30
Jahangirabad	3,648	657.00	1292.00
Bhoipura (MLB College)	3,648	372.3	784.75
Seepage from Upper lake	2,280	9.12	40.15
Leakage from pipe (Upper lake)	1,368	5.47	28.47
Kamal Park	10.032	1135.15	2452.80

Cultivation of Lotus in the Lower lake causes land mass formation:

Weeds growing inside the Bhoj wet land have assumed alarming proportions, in the course of time. Due to death and decay these weeds add to the sediment load thus progressively reducing the water holding capacity of the water bodies besides adversely affecting the quality of water. Though the weeds do absorb a part of the nutrients during regeneration, the nutrients are again returned to the system as they go through their life cycle, thus accumulating nutrients year after year.

Fertilizers:

Development of agriculture has undergone tremendous modernization. Improved and hybrid seeds together with various agrochemicals are used to increase the crop production. In order to maintain the fertility of soil various fertilizers particularly **synthetic** ones are used so as to replenish the various nutrients in the soil. Soil nutrients fall under two categories, Macronutrients (carbon, hydrogen, oxygen, nitrogen, phosphorous, sulphur, potassium, calcium, magnesium and iron) and micronutrients (manganese, copper, molybdenum, zinc, boron and chlorine), the former is required in large quantities while the latter are needed in very small amounts.

Of all the nutrients, nitrogen, phosphorous and potassium (NPK) are important and needed to be replenished in fields as they are required in greater amounts and are depleted by repeated cultivation.

The common sources of these elements used in India are: sodium nitrate, ammonium sulphate, ammonium nitrate, ammonium chloride, urea, calcium ammonium nitrate, super phosphate, bone meal, rock phosphate and calcium magnesium phosphate.

Excessive fertilizers when discharged into water resources, support luxuriant growths of blooms of algae. Algae on death, release their component inorganic and organic substances back into the water and so become pollutants themselves. Excessive growth of algae robs the water of its oxygen and can spell disaster or death to fish and other aquatic biota.

Even though nitrogen in fertilizers is one of the most highly mobile elements, excessive and indiscriminate applications of nitrogenous fertilizers to soils can lead to its accumulation to such a stage that the plants begin to absorb excessive amounts and even then some of the excess amounts present in the soil gets leached off through the soil into groundwater, lakes, streams, springs.

Such nitrates get accumulated in water and if drunk by cattle (or human) these nitrates are reduced to toxic nitrites by intestinal bacteria. Nitrites can cause a serious disease called methaemoglobinemia which can inflict serious damage to respiratory and vascular systems and may even cause suffocation.

Inorganic fertilizers often change the mobility status of nutrients in soils and water. It also stimulates weed growth in crop fields. Excessive use of synthetic fertilizers leads to disturbance in the ionic balance equilibrium in soils, often leading to high acidity, nutritional imbalance, shortage of certain trace elements and molybdenum and selenium toxicity.

As such, use of green manure and bio-fertilizers has been suggested to be the best method of fertilizer application. As the nutrients released by them are on a slower pace and as such, the losses/ runoff loads are minimized. This has a bearing on the maintenance of the healthy metabolism of ecosystem.

Pesticides:

Pesticides are biologically active chemicals used for pest control. But their spectrum of activity often extends far beyond the pests and justifies the more applicable term biocide.

Pesticides are widely distributed by natural means but unlike such natural pollutants as dusts, they tend to retain much of their biocidal activity for fairly long periods.

Huge amounts of different kinds of poisonous agricultural chemicals are being used these days and the whole biosphere is being increasingly poisoned and polluted as a consequence. Agro systems are especially vulnerable to the wide range of pesticides applied to maximize growth of crops.

Human beings are exposed to pesticides mainly through the intake of food and water but also by inhaling contaminated air.

In lakes, biocide dispersal involves adsorption to silt and deposition of residues and silt on lakes bottom, from where they can be dispersed, preserved and concentrated in the lipid pool of the ecosystem by means as bacteria and food-web transmission leading ultimately to the final consumer. It is the relatively inert lipid fraction found in the ecosystem that acts as preservative for the residues.

Pesticides used initially around the world were simple stomach poisons and mainly contained arsenic. There after organochlorines, organophosphates and carbamates have been used. Of these organochlorides are highly toxic, persistent and bioaccumulates, while phosphorous containing pesticides (usually insecticides) are relatively immobile in comparison to the organochlorine pesticides. They rapidly degrade in the environment and are seldom detectable in aquatic ecosystem except locally after application and immediate runoff.

The organophosphorous pesticides thus do not generally fit the criteria of serious long term aquatic ecosystem contaminants.

Carbamates (mainly insecticides) usually degrade rapidly after use, are relatively immobile and seldom detected in aquatic ecosystems.

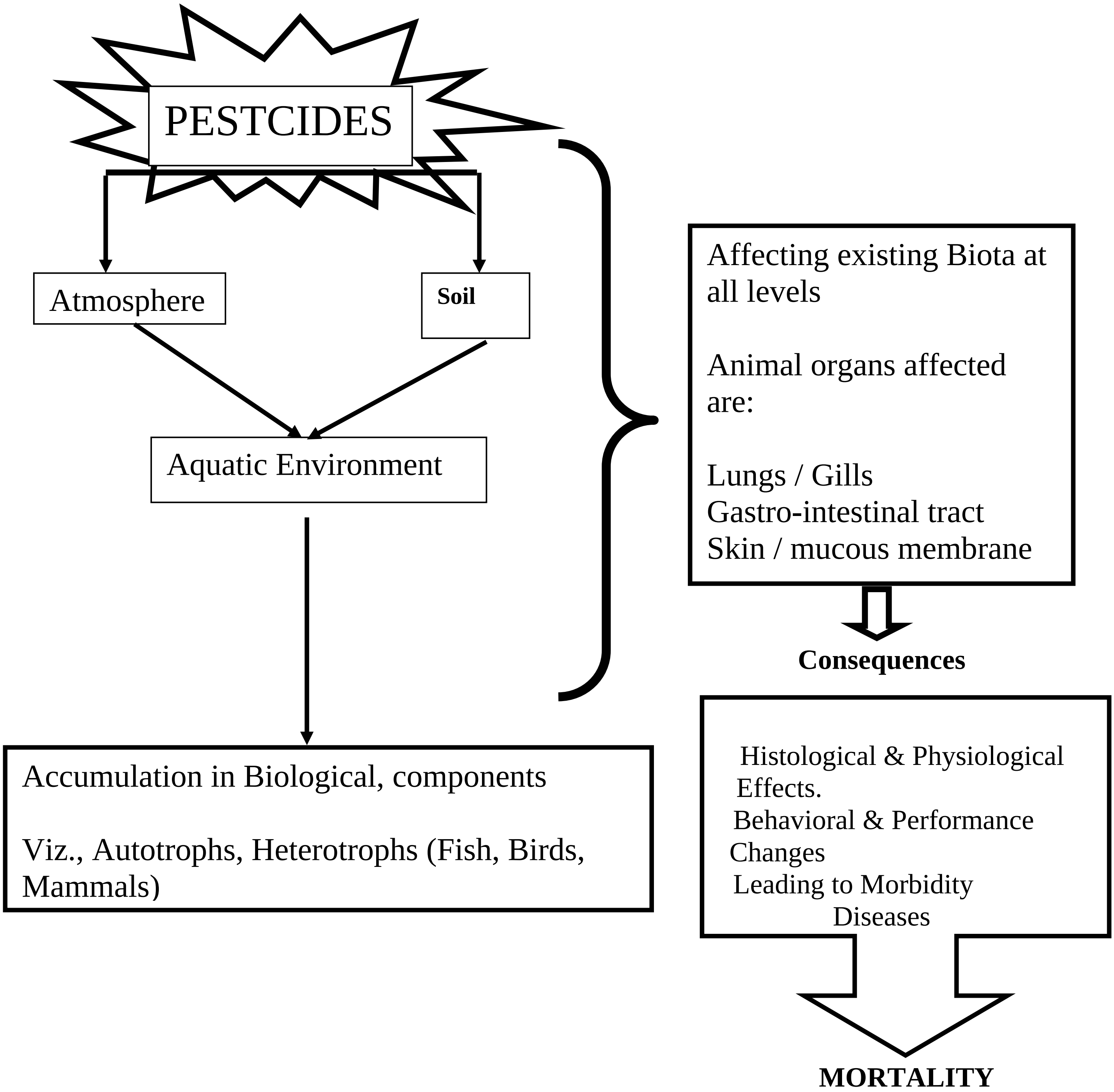
Thus, the carbamates like the organophosphorous compounds are also not considered long term serious aquatic ecosystem contaminants.

Pesticides no doubt help --- in the protection of crops, control disease vectors (e.g., malaria, yellow fever), as protection of materials (incorporation in paints, timber, glues, plastic sheeting and to prevent attack by insects), in industry, in domestic house hold of garden spray and ectoparasites of pet animals, and as an application to clothing, skin and control of fleas, lice and mites---yet they often strike not only the intended pest but also several non target organisms as well. They have great affinity for animal fat and are highly soluble in it. Since they are generally stable compounds they get accumulated in animal bodies and their concentration is built up geometrically as they are transferred to different stages of food web leading to bio magnification. This may result in faunal displacement and other population changes besides causing mortality of major land and water flora and fauna.

Chlordane, another insecticide, readily absorbed through skin and other portals causes stimulation of the Central nervous system. Aldrin and dialdrin also act on Central nervous system and may cause death in human beings. Several pesticides are teratogenic, mutagenic or carcinogenic.

Repeated application of pesticides has been found to be responsible for pests becoming resistant to pesticides. As such, farmers are forced to use higher and higher doses of more expensive and more toxic chemicals. This effect is called pesticide treadmilk where farmers use larger proportions of their income on pesticides without any increase in their yield. This has happened with cotton in India. Just to sustain their cotton yield, farmers now apply up to forty times more insecticides than they did earlier.

Thus to sum up it has been found that synthetic pesticides used for specific purpose, do not get restricted at the target site but find an entry into the various components of the ecosystem as depicted below:



Schematic representation of the effect of pesticide

The above mentioned routing of the pesticide forewarns the consequences of chemical compounds used extensively. As the retention of chemical pesticide is bear minimum at seat of application as most of it finds its way into the various fractions of the ecosystem.

Pesticides

Most of the more extensively used organophosphate and carbamate pesticides are broad spectrum insecticides and are toxic to aquatic and terrestrial vertebrates. These chemicals act rapidly through interference with cholinergic nerve transmission and require only brief exposure to kill or incapacitate most animals. These compounds are comparatively labile in a circumneutral-to-basic environment and are efficiently metabolized by most invertebrates, their environmental presence may be extended in an acidic medium (eg pH 4-6.5) such as soils, sediments, and water common to regions prone to acid precipitation. Continued hazard in both aquatic and terrestrial systems is documented for months after application in association with run off into streams and ponds. There is also the potential for significant hazard to grazing vertebrates, which persists for systemic organophosphates that are metabolized in plants to highly potent sulfoxide and sulfone degradates. It is suspected that chemical incorporated in plants is less easily perceived during feeding and therefore potentially more hazardous than contact poisons. The secondary poisoning of birds and mammals is generally believed to be due to the fact that the prey is simply a conduit for exposing predators to unaltered chemical. That is, chemical in the gut of birds and mammals, mucous covering of aquatic animals, and mucous or cuticle of terrestrial invertebrates is the likely target rather than active chlolinesterase in postabsorptive tissues. Surveys in India have revealed contamination of bovine milk and its products with high levels of DDT and HCH residues.

The potential for accumulated effects (ie increased ChE inhibition) over time may be extended substantially from repeated exposures to contaminated habitat and repeated pesticide application

Organochlorine pesticides, although frequently regarded as uniformly highly toxic and Persistent to the organisms and the ecosystem as a whole, are a diverse group whose toxicity and persistence are highly variable. A marked decline in the population of American robins was linked by the early 1950s to DDT. It soon became evident that ecosystems with bald eagles, osprey, brown pelicans and populations of fish eating mammals were at risk. The presence of these compounds in the environment have generated increased international concern. DDT, dieldrin and chlordane and other persistent organic pollutants (POPs) have even found their way to the polar regions and have caused serious health problems in humans, birds and animal populations. Although their use is restricted or banned in most developed countries, they are still being manufactured in many developed countries them for export and remain widely used in developing countries. India has banned chlordane and heptachlor and is phasing out DDT. The concentration of organochlorine and organophosphate pesticide have also been reported in some of the fish, particularly plankton feeders, was found to be appreciable (Jaffery et al, 1993).

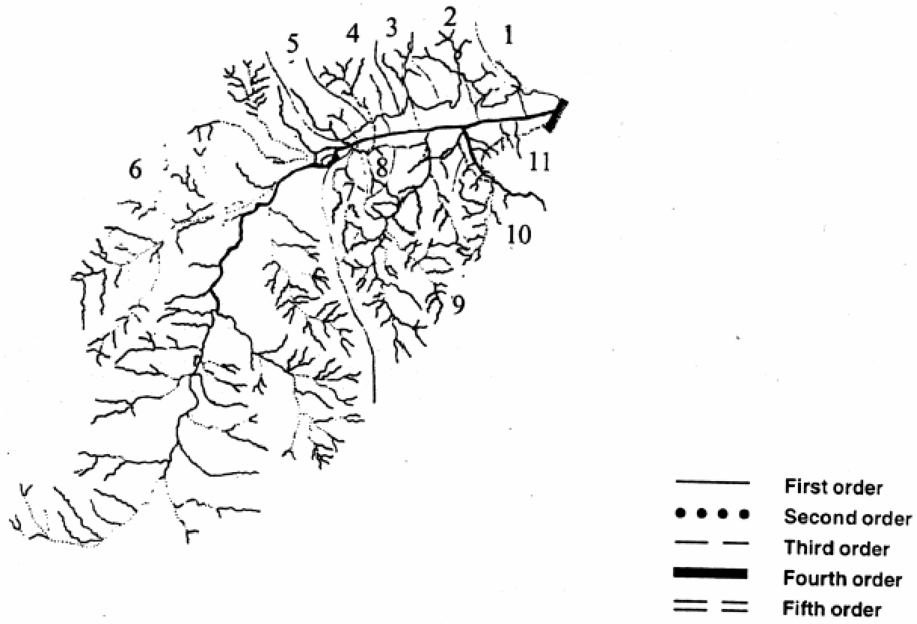


Fig. 1 Drainage Pattern map of Bhoj Wetland showing 11 sub water shed basins

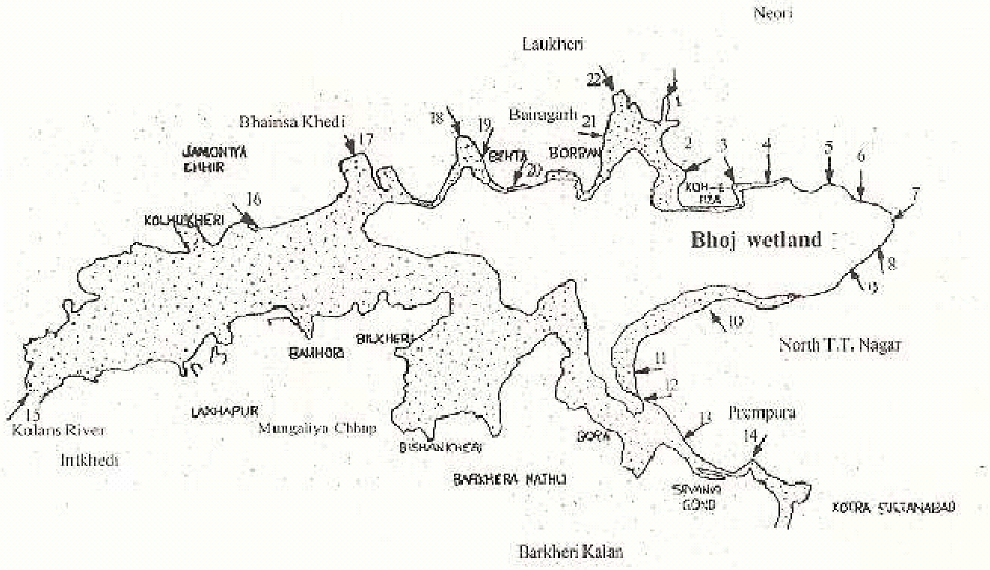


Fig. 2 Input Nallas into the Bhoj wetland (Dotted portion depicts silted area)

Fig 3. Land use / Land cover pattern of Bhoj wetland catchment area 1984

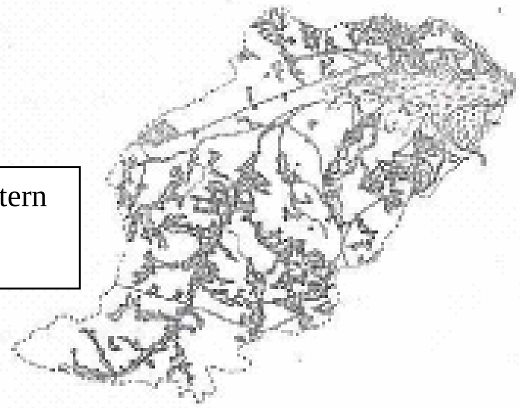


Fig.4 Land use / Land cover pattern of Bhoj wetland catchment area 1988

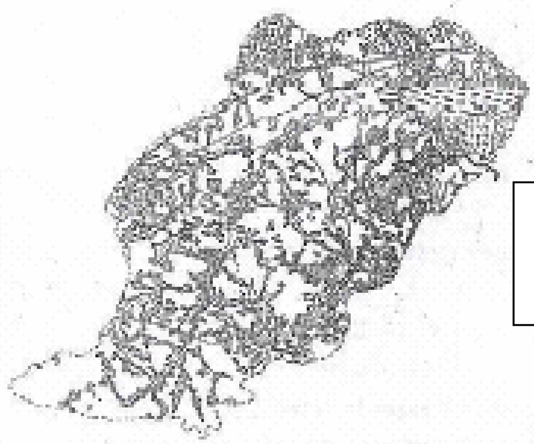


Fig.5 Land use / Land cover pattern of Bhoj wetland catchment area 1994

ALSO SEE COLOURED MAPS INSTEAD OF Fig's 3-5

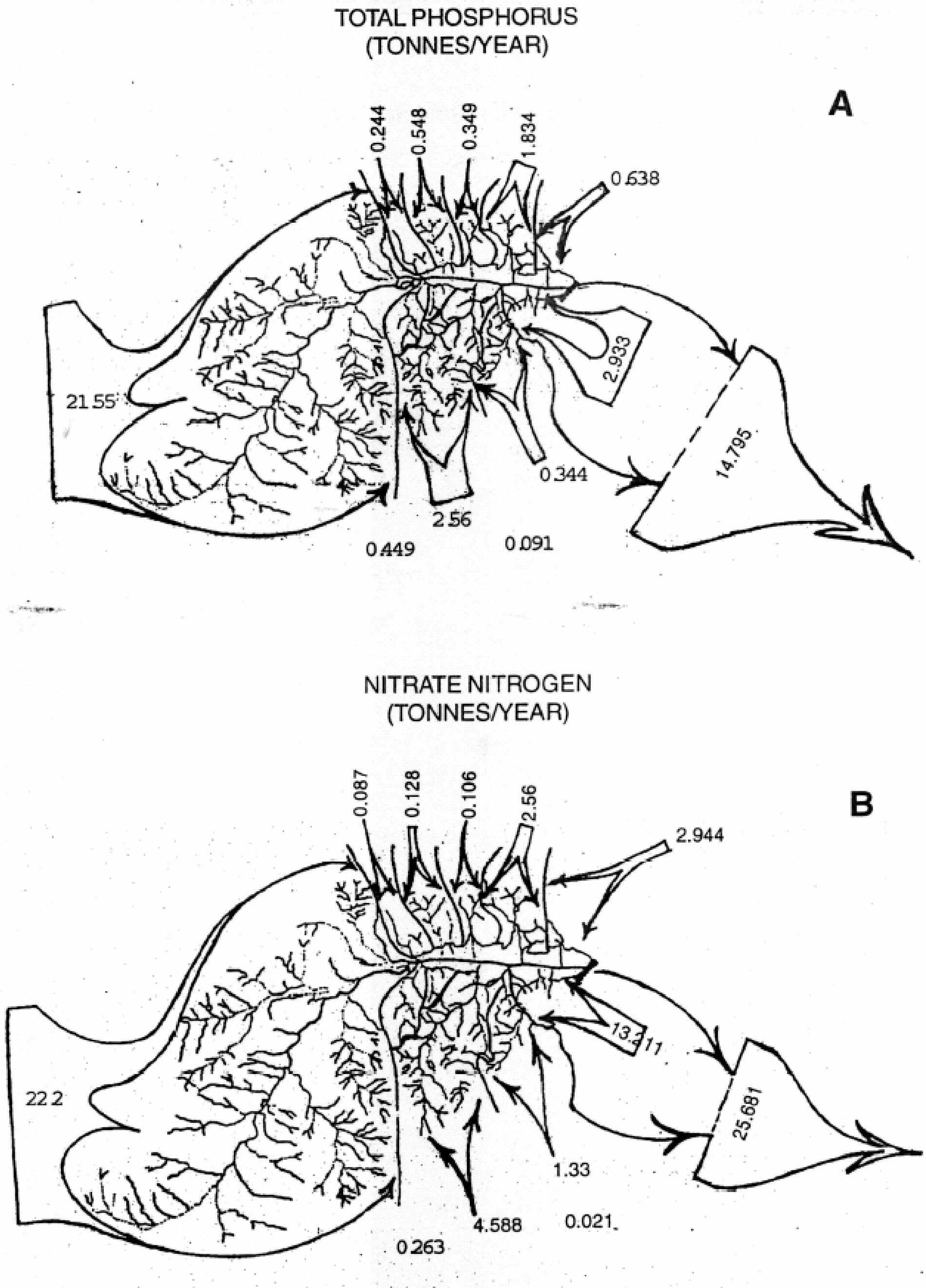


Fig.6 Input of Total Phosphorous and Nitrate nitrogen in tones from different watershed areas on yearly basis (Scale: 1cm thickness = 5 tonnes)

Origins of pesticide entry into water

A number of pesticides detected in water invite attention towards determining the frequency and magnitude of contamination from the catchments area. For such measures surface water catchments have been designated as the management unit.

Agricultural point & diffused sources of contamination which impact on the aquatic environment and cause transgressions of environment quality standards are to be targeted for remedial action or change of activity.

A number of potential entry routes have been identified, which vary according to the nature and properties of the active substance and the prevailing agroclimatic conditions *e.g.* Carter (1999), Notenboom *et al.* (1998). Entry of pesticides into water has been shown to occur in some circumstances and it is now increasingly recognized that there are also a number of other entry routes, in addition to diffuse losses, which arise from non-approved use, poor practice, illegal operations or misuse (Table 1).

Table 1 Sources of pesticide entry into water and water source type predominantly affected

Entry source	Entry route/cause	Main water source type affected
DIFFUSE	spray drift	ditches,streams, ponds rivers
	volatilisation and precipitation	ditches, streams, ponds, rivers
	surface runoff/overland flow	ditches, streams, ponds, rivers
	leaching	groundwater
	throughflow/interflow	ditches, streams, ponds, rivers
	drainflow	ditches, streams, ponds, rivers
	base flow seepage	groundwater /surface water
POINT	tank filling	groundwater /surface water
	Spillages	groundwater /surface water
	faulty equipment	groundwater /surface water
	washings and waste disposal	groundwater /surface water
	sumps, soakaways and drainage	groundwater /surface water
	direct entry including overspray	ditches, streams, ponds, rivers
	consented discharges	streams, rivers

Source :

Diffuse – (non point) indirect entry into water

Pesticides are generally applied for agricultural purposes on a field scale to land where a microbiologically active soil layer is present and where degradation and dissipation processes can take place. The active substance and / or its metabolites usually have the opportunity to move through the soil layers in solution or sorbed to soil particles before entering water via artificial drainage systems or as surface or sub-surface flow, leaching or by-pass flow. Groundwater and surface water bodies can be affected. Spray drift and pesticides in precipitation can also considered to be a diffuse source of surface water contamination.

Point – direct entry into water

Water contamination derives from a localized situation and enters a water body at a specific or restricted number of locations. Approved point source contamination exists in the form of consented discharges e.g. from vegetable washing plants, whilst

Semi-point sources can occur when pesticides are applied to discrete or restricted locations e.g. roadsides or railways. Non approved contamination events derive from spillages or discharges of product, tank mix, waste or washings directly to surfaces or drainage systems which can enter surface water or via soakaways to groundwater.

Volatilisation and precipitation

Volatilisation can be another pathway by which pesticides are lost from target areas after application and whilst most losses do not exceed 20%, for very volatile chemicals losses can be as high as 90%. However, those pesticides which are typically detected in water sources are not likely to be of a volatile nature. Typical losses for atrazine would be <5% in one month, simazine 1% in 24 days, alachlor 26% during 24 days and triallate 17% over 67 days (Taylor, 1995). Incorporation into the soil profile can significantly reduce losses. Pesticide sorbed to fine soil particles may also enter the atmosphere and be re-precipitated. A number of plant protection products have been monitored in rainfall at low levels particularly during and after the application period. A desk study report (Dubus and Hollis, 1998) reviewed and summarised the existing data relating to long distance aerial transport and subsequent atmospheric deposition of pesticides. Approximately 70% of the 99 pesticides analysed for in rainwater were detected, although the limits of detection for many of these substances are considerably below any environmental quality standard. In agricultural ecosystems, impacts of pesticides via aerial deposition are negligible and insignificant compared to that from their direct agricultural application.

Surface runoff / overland flow :

When the infiltration capacity of an application surface is exceeded water, soluble residues and residues sorbed to fine particles can move across an application surface. Losses from agricultural fields are typically less than 0.05% (Wauchope, 1978; Williamson and Carter, 1991) unless extreme rainfall falls within 1–2 weeks of application of the applied active substance. Losses can be environmentally significant at the local level due to specific agroclimatic conditions and those soils which have the potential to slake or cap, or are situated on steeper slopes, can be particularly susceptible to surface runoff. Leaching is a major process for the transport of soluble to ground and surface water. Leaching residues may move directly to underlying groundwater or may be transported laterally to surface waters. Losses of applied active substance by leaching can, in exceptional cases be as high as 5%, but are typically less than 1%. Losses can be greater when soil water moves rapidly as preferential flow, through the soil via cracks, fissures or macropores since residues have less opportunity to dissipate. In some soil types, residues sorbed to soil or organic particles can be transported from the soil surface suspended in leachate water. Strongly sorbed active substances which do not normally leach can be transported in this way and Hardy et al. (1998) report the transport of diflufenican from a noncalcareous topsoil to surface water. The extent and ecotoxicological significance of this transport mechanism in Europe has not been determined but it will be more important for compounds with high sorption values.

Drainflow and throughflow:
Land drainage design has as its objective the removal of excess water from soil or the land surface. Large scale attempts have been made for at least two centuries to

Point Sources
Farm yard activities (e.g. tankfilling, spillages, faulty equipment, washings and waste disposal, use of sumps, soakaways and drainage) Some of the most serious cases of water contamination have arisen from misuse, accidental spillage, or inadequate handling /storage conditions.

Direct contamination and overspray:
Overspray of surface waters during the application of pesticides is not an approved use. It is unknown how frequently it might occur but its impact could be very significant. This is illustrated by the fact that three 200 µm diameter spray droplets from a spray mix containing 1 kg ha–1 of active substance can cause contamination of one litre of water to 0.12 µg L–1. Granular formulations applied using spreaders may also enter water courses directly.

Spillages directly into surface water have occurred and can cause extensive contamination. Contaminated vehicles fording surface waters are also point source contributors of pesticide movement to water.

Consented discharges

Industrial and agricultural activities can give rise to waste which can be approved for discharge into surface waters. Consents vary according to concentration of residues at the discharge point and the nature of the receiving water. Consents might also be given for disposal of wastes via soakaways which might drain to surface or groundwaters. These point sources can be significant causes of water contamination.

Measures to reduce levels in ground and surface water

Stakeholders and their interests

Action and responsibility to prevent or minimise the presence of pesticides in water lie with a number of stakeholders (farmers/users, regulatory authorities, agrochemical companies, water companies, research and advisory organisations, environment agencies, heath and safety assessors, quality assurance schemes, training agencies and the general public). The range of stakeholders and the different interests or requirements with regard to the presence of pesticides in water means that it can be difficult to introduce measures to reduce or prevent contamination which are acceptable to all parties. There is now an increasing trend for representatives of these organizations to collaborate and to seek solutions, which are acceptable to all parties. An example of this collaboration is demonstrated by the Dammbach Watershed project in Westphalia, Germany which involved the Chamber of Agriculture, three agrochemical companies, AgrEvo, Rhône-Poulenc Agro, Stefes and the water company Gelsenwasser AG. The partnership focused on tank mixing, rinsing, reductions in use and improved spraying practice. This combined stewardship has achieved a 30% reduction in IPU loadings over a two-year period (Bach 1999). Other stewardship initiatives include that from Novartis Agro S.A. in France who have produced a colour leaflet and CD-ROM, which takes the reader/viewer through a series of cartoon images depicting a farmer undertaking a spraying operation (Novartis, 1998). The system provides an interactive quiz to provide training which highlights bad practice and provides information on correct practice. An example of another initiative to improve water quality is that promoted by the Belgian Federation for the Water Sector (BELGAQUA) and the Federation of Producers and Distributors of Pesticides in Belgium (FYTOFAR). After extensive discussions between the two parties agreements were reached to improve spray operator training and user systems and to encourage technological developments. Further co-operation has enabled an investigation of the procedures required for removal of pesticides by water treatment and also the publication of monitoring results. In Brittany, France, whereby a number of agencies including the industry association have developed an action plan to reduce pesticides in surface waters and similar co-operation is taking place in other regions such as Centre and Lorraine. A Danish initiative promotes good practice for mixing, spraying and waste disposal, particularly with respect to point sources of pesticides. Such stewardship activities are amongst the actions encouraged by the European Crop Protection Association (ECPA) who issued, in 1996, a declaration on European Water Policy which requires its national associations to comply with the following requirements:

- Development of products to ensure no harm to human health and the environment;
- Promoting the use of products in accordance with good agricultural practice;
- Ensuring that all the necessary information to avoid risk of pesticide entry into water during Transportation, storage, use or disposal is available to all parties;
- Development of suitable analytical methods for water and making these available to all appropriate authorities;
- Volunteering of expertise to assist with the development of EQO's and EQS's for various water bodies;
- Any other actions or activities which aim to improve the safety and quality of all water resources.

Methods to reduce pesticide entry into water

The complex nature of causes of water contamination means that there is no universal single solution and therefore approaches must be site specific. Site solutions will need to combine a number of these methods as several pathways may be responsible for any given contamination event. The difficulty which arises is that the cause of water contamination cannot usually be attributed to a specific location or farm. Water quality monitoring data reflects an amalgamation of water discharged within a catchment and unless intensive monitoring is taking place throughout the region it would be difficult to attribute any concentration to any particular source. Research results and some site specific monitoring must be used to determine, by extrapolation, where problems might arise in other locations and then expert judgement used to determine priorities in terms of effort to reduce risks. Actions to reduce pesticide entry may arise from voluntary effort by farmer actions, or stewardship programs or compliance may be required under national or EU legislation.
The methods can be considered as physical, engineering and educational solutions.
Physical solutions deal with the infrastructure of the farm itself. They would include the location and use of hard standing, presence of a biological degradation system, e.g. a Bio-bed or reed bed, the characteristics of the pesticide store, drainage systems within the yard and within fields and their connectivity to surface and groundwater and the establishment of buffer zones. Engineering solutions refer to changes in machinery such as the adoption of low

drift technology, sprayer testing and direct injection technology for tank filling. Educational solutions are generally directed at the land owner/ spray operator through certification systems and subsequently to improve awareness of the impact of certain activities, particularly those associated with waste and washings, spillages in the yard and from spray drift or overspray.

Management practices
Improvements in management practices are probably the most important actions which can be made to provide immediate improvements in water quality. A primary and essential action is to improve the awareness of spray. As protecting water quality is a top environmental priority as we approach the twenty-first century.

Pesticides and Water Quality

Using pesticides effectively while maintaining water quality presents an important challenge. As citizens, we must recognize the significant role of pesticides in maintaining a high quality of life. We must acknowledge that the effective production of food and fiber relies on pesticides to control weeds, insects, and plant diseases that interfere with the growth, harvest, and marketability of crops.

Human and environmental health may be threatened when excessive concentrations of pesticides enter surface or ground water.

Fate of Pesticides in the Environment

The interaction of pesticides with soils, surface water, and ground water is complex. Pesticide fate is controlled by numerous simultaneous biological, physical, and chemical reactions. Comprehending the fate of pesticides requires an understanding of certain processes: transformation; transfer; and transport. Transformation refers to biological and chemical processes that change the structure of a pesticide or completely degrade it. Transfer refers to the way in which a pesticide is distributed between solids and liquids (e.g., between soil and soil water), or between solids and gases (as between soil and the air it contains). Transport is the movement from one environmental compartment to another, such as the leaching of pesticides through soil to ground water; volatilization into the air; or runoff to surface water.

When a pesticide is applied to a field, certain reactions follow. Foliar-applied pesticides stick to leaves, where they are absorbed. But rainfall inevitably washes some of the chemical off the leaf surface onto the soil below; and some may be transformed by sunlight. Soil-applied pesticides generally interact first with moisture around and between soil particles, influencing how the chemical ultimately will react in the environment. Thus, a 'soil solution' can be viewed as a chemical staging area for most reactions controlling environmental fate. For instance, sorption processes (transfer), degradation by microbial and chemical reactions (transformation), volatilization to the atmosphere, leaching into deeper soil profiles, and overland flow (transport) all occur predominantly from soil solution.

Sorption:
Sorption is a transfer process by which pesticides are dispersed between solid matter and water, in soil; it is important in regulating the concentration of pesticides in soil water. One important environmental sink (retention or storage site) for many pesticides is organic matter. The amount of pesticide sorbed is largely a function of the total amount of organic matter (sorption regions) in the soil. Sorption to clay mineral particles also occurs but usually is less significant than sorption to organic matter in determining environmental fate, unless the soil has very low organic matter content.

Many pesticides develop a charge as the result of soil solution pH (a measure of acidity); i.e., neutral pesticide molecules can become ionic (charged) and more reactive. If the pH-induced charge is positive, the pesticide can bind to negatively charged soil. If the induced charge is negative, the pesticide may actually be repelled from the negatively charged surfaces of soil solids.

Sorption to soil particles is also dependent on soil water content because water is necessary for chemical movement; and water molecules will compete with pesticide molecules for attachment sites on clay and organic matter. Therefore, pesticide sorption tends to be greater in dry soils than in wet soils. Decreased soil water content forces the pesticide to interact with soil surfaces; however, the amount of sorption also depends on the type of clay and organic matter content.

The bond between a pesticide molecule and a soil particle determines, to a large degree, the environmental fate of the pesticide. For instance, pesticides that are tightly sorbed to soil particles have decreased mobility and are less likely to contaminate ground water. The bond may decrease the rate at which the pesticide is degraded by soil microbes, leading to longer environmental persistence. Pesticides strongly sorbed to soil particles may travel primarily with eroded soil and enter surface water, while weakly sorbed pesticides that are more water soluble may be released into soil water solution and enter surface water as runoff.

Runoff and Erosion

Runoff movement of water across the soil surface occurs when water collects (due to rainfall, irrigation, or melting snow) at a rate faster than it can infiltrate the soil. As rain falls, small soil particles become dislodged and are carried laterally by water in a process known as erosion. Because pesticides are applied directly to the soil, large amounts eventually end up there; and as water runs off and soils erode, dissolved and sorbed pesticides go along. Runoff and erosion have the potential to move more pesticide off site than leaching, due to the fact that runoff is a surface phenomenon. Surface runoff and erosion move pesticides and other pollutants laterally from points of higher elevations to collection points (streams, rivers, ponds, lakes) at lower elevations. Climatic factors such as rainfall timing, duration, and intensity, and surface features such as slope length and grade, soil permeability, and surface cover greatly influence the degree to which pesticides are mobilized by runoff and erosion. Similarly, pesticide management factors may significantly affect runoff; for example, a soil-incorporated pesticide is less likely to run off site than the same compound applied to the soil surface.

The results of environmental fate studies are not always sufficient to estimate concentrations of a pesticide in aquifers or surface waters when the chemical is used in different geographical areas, or to define specific areas where water contamination might occur. Therefore, presumptive decisions on use restrictions or limitations must be made for pesticides with the potential to affect water quality. These decisions might be made long after registration, as cumulative information warrants; labels may be modified to be more or less restrictive, depending on the results of surface and/or ground water monitoring studies.

Screening Pesticides for Runoff Potential

The runoff potential of a pesticide is influenced by three factors: type of soil; slope of terrain; and the intensity and timing (with respect to pesticide application) of rainfall. All three factors should be considered when estimating runoff potential. A nonpersistent pesticide (i.e., one which does not sorb to soil particles or organic matter) can be transported from its application site to major bodies of surface water in as little as a few minutes or hours when heavy rains occur shortly after application. A pesticide exhibiting strong sorption to soil usually will have a lower runoff potential than a pesticide exhibiting weak sorption, but it can still reach surface water if sorbed to soil particulates eroding with the flow.

Ecological Risk Assessment

MCLs are designed to ensure that adverse human health effects do not accrue from pesticide use, but they do not address potential adverse effects on non target plants and animals; however, pesticide regulators are bound by legislative mandate to ensure that pesticide use does not cause adverse environmental effects. Various (plant and animal) organisms undergo a series of toxicity tests to determine what pesticide concentration levels might cause adverse effects. Some involve aquatic organisms such as fish or algae which might be exposed to pesticide residues entering streams and lakes as runoff from urban and/or rural sources.

Herbicides tend to be more toxic to plants than to other organisms affecting terrestrial plants at concentrations of only a few hundredths of a part per billion in irrigation water.

Herbicides:

Herbicides differ from insecticides in killing both desirable species as well as intended target. Their impact may not be limited directly to the plant community or agriculture crop but they may also act indirectly through effects on such soil microbes as nitrogen fixing blue green algae and bacteria. This in turn may impair the growth and production of higher plants. Herbicides that drift from a treated crop to a nearby crop also cause serious environmental problems. Persistent use of herbicides can injure crops planted in rotation.

Acute doses of diphenyle herbicide like 2,4-D; 2,4,5-T in man leads to fibrillary twitching of muscles, hyporeflexia and urinary incontinence. There is drastic increase in cell proliferation in phloem which results in blockage of nutrient transport and formation of harmful lesions.
If death is delayed, myotonia, stffness, atoxia, paralysis and coma are observed. It produces teratogenicity in mammals and leads to delay in the maturation stages of sperms.

Remedial measures:

The harmful, long lasting impacts of these chemical pesticides strongly points towards the use of pesticides which will mainly be biorationals (chemicals produced naturally by plants and animals and ones that do not necessarily kill). Further chemical pesticides are by no means the only way to control pests; predators can also be used for the control. Even pathogens such as viruses and bacteria are now employed for controlling pests. Low value crops (Decoy plants) are cultivated to attract pests away from high value crops. Rotation of crops prevents a particular pest to get established at a particular site. Juvenile hormones can be used that prevent insects from completing their life cycle. Sex lures and other biochemical’s can be used that can regulate pest behavior. Use of degradable pesticides such as organic phosphates can be used to avoid non-degradable ones.

RECOMMENDATIONS:

1. The increase in human activity in the catchment has been found to be responsible for the enhancement of nutrients in the water body. In this respect it is important to consider the shoreline habitats, and in particular the abundant littoral wetlands as they absorb nutrients and serve as a chemical buffer between land and water body.
2. Develop bunds for checking soil erosion and subsequent input of nutrients input the water body. Terrace type of farming on slopes should be promulgated.
3. Use of synthetic fertilizers should be avoided as loss of nutrients and other elements through surface runoff is maximum from these chemical fertilizers.
4. Use of organic manure in the fields leads to release of nutrients and other elements at a Slower pace and thus the loss from such organic fertilizers is minimized
5. Upgradation of the catchment areas by:
    a) Check on changing land use land pattern.
    b) Restricting proliferation of build up area.
    c) Re-vegetation of the fallow land.
    d) Cascading / barricading agricultural lands around the wetland.
    e) Discouraging the development of Poultry farms / animal farms in the riparian areas of the wetland.
    f) Putting a restriction over the use of chemical fertilizers in greater proportions
    g) Encouraging the use of organic manures.
    h) Encouraging the growth of disease resistant crop varieties in the riparian as well as in the whole catchment area.
6. Regular input from the point sources (drains/ nallahs) should be stopped and needs to be diverted effectively even the spillage from these drains should not be allowed.
7. Construction of a pavement road all along the fringe area of the lakes/ wet land. This will stop encroachment and will put a check on the input from the diffused source as well.
8. Motorized boats plying in these water bodies should be stopped.
9. In order to reduce the negative impacts of chemical pesticides on the metabolism of Bhoj wet land farming practices need to be improvised by adopting eco friendly techniques by way of shifting to organic farming practices. This will lead to significant positive outcomes for the ecology of the upper lake and wider societal benefits, including protection of domestic water supplies.

References

Ali, S.A.(1981). Bhopal, Past and Present (a brief history of Bhopal from the horay past upto the present time). Jai Bharti publishing house, Bhopal, pp.450.

Bach, M. (1999) Reduction of pesticide contamination at the catchment level. In: Agriculture and the Environment – Challenges and Conflicts for the New Millenium.108-115. Ed. S. T. D. Turner and D. Alford, ADAS, Wolverhampton, pp. 108–115.

Bhatnagar, G.P. (1982). Limnology of Lower lake, Bhopal with reference to sewage pollution and Eutrophication. Technical report (Man and Biosphere Department of Envoironment, govt. of India, New Delhi). Pp.77.

Bhoj wetland detailed project report, on deweeding of Upper and Lower lakes (1998). Lake conservation and management project. Prepared by R.P. Field survey and Engineering Services Company for Capital Project Div. P.H.E. Department, Bhopal.pp.87.

Carter, A. D. (1999) Leaching Mechanisms, In: Pesticide Chemistry and Bioscience, the Food-Environment Challenge. Eds G. T. Brooks and T. R. Roberts, 291–301. The Royal Society of Chemistry, Cambridge, UK.

Dubus, I. G.; Hollis, J. M. (1999) Pesticides in rainfall in Europe, a review. Research report MAFF PL0528 for the Ministry of Agriculture Fisheries and Food. Soil Survey & Land research Centre, Cranfield University, Bedford.

Eck, P.. M.L. Jackson, O. E. Hayes and C. E. Bay. 1957. Runoff analysis as a measure of erosion losses and potential discharges of minerals and organic matter into lakes and streams. Summary report, lakes investigations , Univ. of Wisconsin, 13 pp.

Eriksson, Erik .(1955). Air borne salts and the chemical composition of river waters. Tellus, V.T.pp. 243 - 250

Hardy, I. A. J.; Carter, A. D.; Leeds-Harrison, P. B. (1998) Water Quality from contrasting drained clay soils: The relative importance of sorbed and aqueous phase transport mechanisms. Abstract 6C-018 9th International Congress Pesticide Chemistry, The Food-Environment Challenge. Royal Society of Chemistry, London.

Jeffrey Wolt, Henry Nelson, Michael Barrett, Sarah Brichford and Ronald Turco (1993). Purdue Pesticide Pregramme (Pesticides and Water Quality, PPP-35.htm).

Likens, G.F., F. H. Bormann, N.M. Johnston, D.W. Fisher and R.S. Pierce. 1970. Effects of forest cutting and herbicide treatment on nutrient budget in the Hubbard Brook watershed- Ecosystem. Ecological monographs 40(1): 23-47.

Midgely, A. R. and D. E. Dunklee. 1945. Fertility runoff losses from manure spread during the winter. Vermont Agr. Exp. Sta. Bull. 523,19 pp.

Notenboom, J.; Verschoor, A.; van der Linden, A.; van Plassche, E.; Reuther, C. (1998) Pesticides in groundwater: occurrence and ecological impacts RIVM report 601506002 Bilthoven, Netherlands.

Novartis, 1998 Les Bonnes Practiques Agricoles. Protègent l'eau à chaque étape traitement. Novartis Agro S.A.

Rathore, P.S. (1988). Upper lake and Bhopal water supply. Proc. Symp. Past, present and future of Bhopal lakes. 1-6, Ed. Kulshresths,S., Upkar N Adholia, O.P.Jain, and Anita Bhatnagar.

Sawyer, C.N.(1947). Fertilization of lakes by Agriculture and Urban drainage. J. New Englsnd water works Assoc. 61,2,p.109 – 127. In OECD Report, Paris. 1970.

Taylor, A. W. (1995) The volatilization of pesticide residues. In: Environmental Behaviour of Agrochemicals. (Eds: T. R. Roberts and P. C. Kearney), 257-306, J. Wiley & Sons Ltd, Chichester.

Wanganeo, A (1994-95). Impact of Anthropogenic activities on Bhoj Wetland with particular emphasis on nutrient dynamics. First yearly progress report submitted to Ministry of Environment and forests, New Delhi.

Wanganeo, A. (1998). Impact of Anthropogenic activities on Bhoj Wetland with particular emphasis on nutrient dynamics. Final Report submitted to Ministry of Environment and forests, New Delhi. Pp. 82.

Wauchope, R. D. (1978) The pesticide content of surface water draining from agricultural fields – a review. *Journal of Environmental Quality* **7**, 459–472.

Williamson, A. R.; Carter, A. D. (1991). Field studies to determine the potential risk of contamination of ground and surface waters by an autumn and spring applied herbicide in oilseed rape and fodder maize. *Proceedings of the Brighton Crop Protection Conference – Weeds,* **3**, 491–498.

(a) Executive summary:

Impact of agricultural runoff can be vividly found on the macrophytes which record profusion in their growth rate. Higher macrophyte biomass has been recorded towards the “SW” side of the lake on account of nutrients entering into the water body from the predominant agricultural based catchment area. The profuse macrophytic growth on annual basis added sizeable amount to sediments leading to their accumulation and resulting in uplifting of the sediment and ecological succession of the macrophytes. The submersed macrophytes got replaced by emergent & free floating macrophytes on amount of shallowing of the area. This process (ecological succession) has also been found to be responsible for the loss of biodiversity. The economically viable plants have suffered colossal loss. Further, under management programs the removal / deweeding of macrophytes have given a boost to the growth of phytoplankton population leading to the alga bloom formation (on account of release of nutrients) responsible for escalation of water cess charges.

(b) Thus the major negative nutrient impact of runoff from the agricultural land on Lake Metabolism is Eutrophication of the water body leading to loss of biodiversity and the deterioration of potable/ water quality on addition of N, P and K.

(c) Nutrient load is generally associated with fertilizers besides wastewater generated anthroprogenically. Impact from the steep slope is very high in comparison to flat lands (even if they are very close to the watercourses).

(d) Agricultural practices close to the water body and in littoral zone areas is not advisable as it results in direct addition of nutrients and heavy metals into the water bodies, leading to their Eutrophication and contamination.

The length of main streams in small watersheds does not play a significant role with respect to the dilution or getting the impact diffused by the time it reaches the lake.

Dear Ashwini

Requires an Executive summary:A short summary that details conclusions on

a) Impact of agriculture runoff: i.e. does and if yes how agricultural runoff threatens the ecology of the upper lake leading to human, environmental and economic costs.

b) Major negative nutrient impacts on the upper lake: what are the causes- the role of NPK inorganic fertilisers and pesticides associated with the monsoon cropping season and irrigated post-monsoon flood irrigation (this may not be accurate but we need Ashwini to give us lead in simple clear language in ONE sentence?

c) What comprises the nutrient load: i.e. is greatest nutrient load associated with fertiliser A or pesticide B on steep sloping cultivated land (>15 degress, say) or on more shallow slopes near water courses (< 5 degrees).

d) some thoughts on agricultural practices in the litoral zone - are they particularly prejudicial.

e) Recommendations: (specially mention the points that due to complex bio-chemical transferal processes remedial action to reduce agricultural impacts on the health of the upper lake must be inclusive of farming practices throughout the upper catchment zone , and Improved upper catchment agricultural management, particularly conversion to organic farming practices, will lead to significant positive outcomes for the ecology of the upper lake and wider societal benefits, including protection of domestic water supplies.

Main Report:

1. General editing of the report-

a) Appropriate title, say "Technical evaluation of agricultural impacts on water quality at the Bhoj wetlands, MP"

b) Index with titles/page nos.

c) Page nos.

d) Typos/spelling. Particularly, "sorption" - does he mean "absorption"?

e) Maps- the maps provided in the report are very useful. But they have to be more clear in terms of the legends.

   1. Map 1: the rural catchements are not clearly identifiable.
   2. Map 3 is very important and useful, but it is not clear what is the landuse type. more clarity is requiredCan the quality of the maps be improved? I assume they are photocopies.

f) References

g) definition of technical terms- like ambient water, inlet etc

2. More clarity on the section on nutrient budget of upper lake is very important. It is assumed that the testing of the nutrients is done at the point where the stream meets the lake (inlet), but needs to be confirmed.
3. Does (to what level) a land use practice in say the fag end of the watershed impact as much as a land use practice in a land near to the lake in terms of inflow into the main lake? does the length of the main stream matter in terms of the impacts getting diffused by the time it reaches the lake. especially in the context of the study site. I hope you will be able to incorporate and send us the revised report by this weekend.

Regards

Mamta Borgoyary