INTERVENTION INCATCHMENT LAND USE TO PROTECT A TROPICAL LAKE ECOLOGY &ITS WATER STORAGE CAPACITY

[1]PRADEEP SHRIVASTAVA, [2]ABHASWARUP

[1]Department of Environmental Science & Limnology, Barkatullah University, Bhopal 462026 INDIA
[2]Director, M.P. Council of Science & Technology, Bhopal INDIA
E-mail: [1]drshrivastava@hotmail.com, [2]abhaswarup@rediffmail.com

Abstract - Catchment of any lake has always been of great importance while considering its environmental management for its sustenance both in terms of its quality as well as quantity. The present study was under taken on a typical tropical urban lake which is also source of drinking water for population of a capital city. Agriculture is the dominant land use of the basin and has created potential ecological problem to this lake, its storage capacity is depleting at considerable rate and the nutrients with surface runoff is the causes of eutrophication of the lake, agrochemicals used pose potential danger to water quality, which is a serious concern for human health. A change is land use to urban development on limited basis has been seen as a solution that will address the problem of soil erosion and siltation apart from input of agrochemicals joining the lake.

I. INTRODUCTION

Upper lake is in the heart of city of Bhopal and is the lifeline of this capital city of Madhya Pradesh. It was created by constructing an earthen dam (which separates the Upper lake from Lower lake) on seasonal river Kolans by Raja Bhoj of Dhar in the 11th Century A.D. (1010-1055 A.D.) It is the most magnificent of all the lakes and reservoirs in this region and has been alone source of drinking water supply to the 2 million population of the capital until the recent past. It has maximum water spread area at FRL is 32 sq km with average depth of 3 m. 365 sq km of catchment drains surface water runoff into the lake. The upper lake is an east-westerly elongated manmade shallow lake with irregular margins and luxuriant growth of aquatic vegetation. The lake area is bounded between the latitudes $20^0$1 0'-$23^0$20' and longitudes $77^0$15'-$77^0$25' as shown in the Survey of India toposheet No. 55 E/7 and 55 E/8. The lake is situated at an altitude of 532 metres above the mean sea level as described by Vyas et al in the paper available on website wldb.ilec.or.jp/data/ilec/WLC13_Papers/S17/s17-17.pdf

OBSERVATIONS

The lake:

Is drained by the 361 km^2 watershed, the main geological formations are Bhandersand stone and Deccan trap lava flows. This contributes to good black cotton soils and with average rainfall greater than 1200 mm and a gentle topography, agricultural is the main land use amongst the 87 villages in the watershed. 80% of the catchment land use is agriculture. Census data from 2001 estimates 14,109 households with 83,909 people living in the watershed (Sachdeva,S. 2009 available on wldb.ilec.or.jp/data/ilec/WLC13_Papers/S8/s8-4.pdf). Over the decade of 1991-2001 its population had grown at about 3.5 per cent per year, higher than the national average of 2 percent. This surge has put the city's available water resources under immense pressure

This lake has been recognized as a Ramsar site under the international Ramsar convention. Several studies have reported its biological diversity rangingfrom106 species of macrophytes, 208 phytoplankto,115 zooplankton,45 species of fishes, 179 avian fauna both migratory and local as well as several species of insects and reptiles and benthic organisms which play important role inecological function of the lake.

Multiple Uses of the lake:

Upper lake is a multiple use water resource and being used for various purposes: primarily for drinking water supply. Among other important uses of the lake, livelihoods of many people are also directly linked to the wetland. A fishermen's co-operative consisting of some 500 families has been given fishing rights by the local authorities. Trapa culture is also practiced by some families. It is also used for tourism and recreation, as wild life habitat and for research and education.

Drinking Water Supply:

The lake is the principal source of potable water supply to the city. In case of normal rainfall the water supply from the lake is 29 million gallons per day (MGD) depending upon the initial water level after the monsoon. About 40% of the city population is still dependent on Upper lake for drinking water supply governed by Bhopal Municipal Corporation (BMC). In addition to this Military township and Railways are using the water for drinking and other Purposes. Among different sources of water for urban population, Upper lake provides 99, Kolar Dam 135 and ground water resource provide 33 MLD of water. With the increasing population of the city, the

projected demand of water was calculated as approximately 344 MLD in 2011 with population of 2 million. The existing water consumption rate by population as reported by BMC is 167 LPCD whereas the required rate of consumption has been reported to be 176 LPCD, on subtracting the loss of water as leakage the actual consumption rate comes to approximately 108 LPCD which is significantly less than the required rate of consumption. Also, the BMC has plans to increase the population coverage for water supply from 67 to 100% and to increase the water supply hours from 45 minutes to 24 hours. All this will lead to increased demand of water for city consumption which would require mobilizing additional sources of water.

Major environmental problems affecting the lake water and its ecology:

Upper lake ecology has been under the influence of several environmental pressures present in its urban and rural catchment, as a result of which its ecology has degraded in terms of water quality and other biological parameters. This has been mentioned in several reports, research articles, observations and monitoring undertaken by the line departments as part of routine monitoring of its water quality and biological parameters. Major environmental problem pertains to pollution caused by direct entry of untreated sewage from urban population of its catchment in to the lake. High values of BOD, coliform & nutrients (N & P), turbidity and conductivity values have been observed by Shrivastava & Josh (1992) Shrivastava et al (1994), Vipin et al available on ilec.or.jp/data/ilec/WLC13_Papers/S17/s17-17.pdf , Mishra (2006) and Upadhyay et al (2012). But even after implementation of the Bhojwetlandrestoration , conservation and protection programme, the ecological quality of this lake has yet to show significant change.

This appears to be due to the impact of other environmental pressure that adversely affects the lake ecological health. The input from the rural catchment and its adverse effects has been reported by Upadhyay et al (2012), Vyas et al (2009) available on 2wldb.ilec.or.jp /data/ilec/ WLC13_Papers/S17/s17-17.pdf, Sachdeva,S.(2009) available on wldb.ilec.or.jp/data/ilec/WLC13_Papers/S8/s8-4.pdf.and the SAPROF (1993) report prepared for the Bhojwetland restoration programme.

Watershed treatment: In order to mitigate inflow of silt, agricultural residues and other wastes into the lakes, 73 check dams made of loose boulder/Gabion structures having cumulative silt trapping capacity of approximately 0.35 million cum have been constructed across 28 inlet channels in the catchment, as reported by Nandi PK in an his paperentitled Management of Upper lake available on http://www.tucson.ars.ag.gov/icrw/proceedings/nandi.pdf .

Agriculture land use and lake ecology: More than 50% percent of village households reported cultivation as their primary income source water and sanitation problem is prevalent in the catchment. Soyabean and wheat grown in the catchment are major crops. Landholding distribution has been reported to show holding of the large farms lands by the general category and OBC class of the society ,whereas SC and ST population have smaller land holding (Hope et al 2006). This may pose, in future, problem while implementing alternative options in agro practices with the objective to protect ecological quality of the lake specially its water quality.The agriculture runoff from the rural catchment enters directly and via streams into lake, predominantly on the south west side and flows from west to east. It affects the quality of water in the wetlands and is a long term threat to the health of the lake. Finally, the bulk of the silt inflow takes place from the rural side of the catchment(Sachdeva,S. 2009) available on wldb.ilec.or.jp/data/ilec/WLC13_Papers/S8/s8-4.pdf.

70% of nitrogen entering inland surface waters in the European Union is from agriculture. Fertilisers and pesticides are widely across the entire catchment agriculture. Hope et al (2007) reported agrochemical application rate for fertiliser ranging from 34-44 kilograms per acre in kharif season. For rabicrop it was between 135-154 kilograms per acre. Pesticide use is concentrated in the kharif season (range 0.67-0.84 litres per acre) with lower application in the rabi season (range 0.05-0.09 litres per acre). Rural sources of agricultural pollution runoff adversely affects the trophic status of the Upper lake (Mishra, 2006). Nitrate concentration of 1.5 milligrams per liter are within permissible limits for drinking water of 50 milligrams per liter (WHO, 2004). However the existing nutrient level in the lake is causative to increased primary productivity in the lake as exhibited by excessive growth of macrophytes (Shrivastava et al , 1992) in the lake.. This also leads to algal growth, high coliform and turbidity in the lake (Shrivastava & Joshi, 1994,Vipin et al, 2009 and Valech et al (1995). This further adds to the existing cost of water treatment for supply to the population for drinking. In case of lake and wetlands, as discussed earlier non-point sources may alone responsible for more than 50% of the total pollution load.

DISCUSSION

Major ecological problem the lake ecosystem is faced with, relates primarily to the erosion of soil from the agriculture land in the catchment. Resulting siltation in the lake has adversely affected the lake storage capacity significantly. Study undertaken on the possible rate of siltation taking place in the lake,

has calculated three different rates at which the silt possibly enters this lake. Upadhyay et al (2012) reported three different scenarios of rate of siltation in the lake by applying different equations,Khosla equation (1953), Dhurv Narayan et.al.(1983) equation and Garde and Kothyari(1987) equation. The three different rates of annual sediment yield calculated using these formulas are 0-22, 5.6 and 1.4 M m^3 respectively with corresponding projected life of the lake as 532 ,21 and 83 years as a result of reduction in its storage capacity due to siltation. The author has found equation of Garde and Kotihyari (1987) to be most close to real situation existing in the catchment as this equation takes into account several geophysical, geographical and climatic factors that potentially can influence soil erosion in the catchment. If this is taken as acceptable prediction, the lake may loose its storage capacity in 83 years and will no longer be able to be source of water for the ever increasing city population. This would necessitate mobilizing other water resources to meet the increasing water demand which would mean additional cost as has been done for augmenting water production by 198 MLD from Kolar Dam, an inter basin transfer, which had an approximate cost of 22 million US$ to meet the water demand for supply at the rate of 135 LPCD as per Bhopal Municipal Corporation report (Bhopal: The water-waste portrait. 71-City Water-Excreta Survey, 2005-06, Centre for Science and Environment, New Delhi, 201).According a calculation, the population of the city has been projected to become approximately 2.3 million and 3.6 million in the year 2021 and 2035 respectively with corresponding water demand calculated as approximately 600 and 800 mld. This would further need another new sources of water for supply to the population. A new inter basin transfer project has been completed successfully which transfers approximately 200 mldof water covering a distance of 70km, from river Narmada to Bhopalwhich is in Betwa (Ganga sub basin) basin. 165 million USD cost of this project has raised the water supply cost to approximately 5USD as against 2.5 USD which was the water supply cost prior to this project. Out of the total water availability in the city from different sources , more than 100% comes from inter basin transfer from Kolar dam and Narmada river. To meetthe ever increasing demand of water by the urban area, there are limited options available to use other water sources in the area. The fore going discussion has explained the status of water availability and its current and projected requirement by the population and the gap in the demand and supply scenario meeting. To meet this increasing water demand, desilting of the lake was proposed under the Bhojwetland project with the objective to create additional storage capacity of the lake equivalent to supply of 7mgd of water to the city. Considering the possible load of sediment yield on annual basis calculated as 1.4 M cum (Upadhyay et al 2012), the capacity of the structures made in the catchment is far below the requirement and is less than quarter of the total silt load that the lake receives annually. Although the post project assessment done by external evaluators Masahisa Nakamura, Victor Muhandiki and Thomas Ballatore under a field survey carried out between November 2006 and May 2007 indicates shortfall in meeting the targets of several subprojects. The planneddesilting proposed for this lake was removal of 5.900 M m3silt of which less than 50% was achieved at the end of the project as a result the storage capacity of Upper Lake was increased by 3.97 M m^3 (4%) against set targets of 6% for Upper lake. Restoring bydesilting these Gabbionstructures for reuse involves a recurrent cost to be paid by the government agency responsible for the lake management. But the cost for this maintenance is finally charged to the people inhabiting the catchment.So far as this population is beneficiary of this lake, it would not be an issue unlike the case of the population inhabiting the upstream of the lake. This would be opposed to bearing this cost for no benefit they get from the lake in terms of water for drinking etc. This conflict becomes major constraint in catchment management, problem is one such issue. Pressure on this water resource continue to work from two direction , one is the increasing pressure from the ever increasing population as a result of the faster rate of urbanization of the city, as described earlier also and the other adverse factor is the rate of siltation of the lake as result of erosion of soil from its

Change in land use as alternative to address the erosion problem:

Agriculture is becoming less profitable due to small land holdings, inadequate irrigation facilities in the catchment and severalother reasons. The farmers in general do not seem to have the level of satisfaction compared to engaging in other livelihood options available to them in the urban setting. Aforestation or reforestation of the agriculture land, as alternative land use is the best option from the environmental view point. This can effectively address the problem of agrochemicals and soil erosion and the resulting siltation of the lake. But there is lack of inclination of the farmers to take to this option as this does not offer potential livelihood alternative to them. It therefore becomes necessary to explore other alternatives which are easily acceptable and can potentially address the problem arising from agriculture being practiced in the basin. It is therefore important to explore possibility to convert land use to urban land use to different degrees depending upon how much of pollution (soil erosion etc) originating from agriculture is required to be reduced. Several techniques, various technologies and legislative framework as acts etc are in place and have been successfully demonstrated in several parts of the country. Standard water sensitive urban design

would provide a customized model for changed land use of the catchment. This design has been successfully conceived and brought into shape by the Lavasa Corporation ltd in the state of Maharashtra in India. System of governance in the area can be different in terms of powers and authority vested with the agency controlling the area. Decision making should be more transparent and involve stakeholders. Process of consultation should precede the decision taken with respect to development and enforcement of law in the region with the objective to effectively manage the environment of the area. Due to high opportunity cost and the preference shown by the people/developers in this area, a separate tax provision can be thought of in order to mobilize extra financial resources. This may be needed for the extra efforts and planning required for lake basin management to achieve the specific objectives identified. Population density has direct relation with the quantity of sewage and solid waste generated in the region. It is therefore important to arrive at decision of population density in the region. Urban area population density of Bhopal is 1320/sq km but the same can be at lower level in the area under consideration so as to sustainably manage the environment of the catchment. This observation is also supported by Sachdeva (2009). Limited urbanization of the lake catchment has been found in certain cases. Lake Biwa inhabits considerable human population in its catchment in its fringe area. Lake Zurich is another example of its high gradient catchment supporting significant human population without any significant adverse impact on the ecological quality of the lake. Management of the basin of Lavasa lake undergoing development for residential purpose will set another example of how adverse impact on lake ecology has been successfully averted for protection of its ecological quality. Based on the principal of water sensitive urban design, the entire catchment area of the lake can be developed with changed land use. This has been demonstrated by the Melbourne Water in Victoria and several other places. This would significantly reduce the soil erosion and siltation of the lake effectively, would bring about ground water recharge, enhanced income generation and livelihood opportunities for the inhabitants of the catchment.

The proposed land use change can potentially reduce the problem of erosion of soil from the catchment and the resulting siltation of the lake apart from eliminating inflowing agrochemicals from surface runoff that empties into the lake. This would greatly protect the storage capacity of the lake so that it continue to remain source of supply of water to the ever increasing population of the city sustainably. Adopting roof top rain water harvesting will enable to collect the water and take for aquifer recharge using the established techniques. Natural drainage in the area requires to be protected as this takes water to the lake as surface runoff. The arising food security issue is serious and needs to be addressed as the expanding population of the area would need this security. The high rate of urbanization results in conversion of agriculture land to residential land use . A trade off can be reached by compromising with reduced rate of land conversion for residential purpose in other areas around Bhopal. This would compensate the resulting loss of agriculture production from land diversion in lake catchment. There are several other Incentive based management options to achieve this goal. In addition to this the sewage water after treatment can be used for irrigation of crops and this has been successfully demonstrated in several cases (Strauss and Blumenthal, 1970) and the intensity of the production system also increased several times in certain cases (Minhas and Sharma, 2004).

REFERENCES

[1] Anon (2005). Bhopal Development Plan, Town and Country Planning Organisation, Bhopal, mimeo

[2] Hope, R.A. Borgoyary, M.&Agarwal, C. (2006). Incentives that work for farmers and wetlands - a case study from the Bhoj wetland, India Project technical report for DFID FRP R8174: "Socio-economic opportunities from upland catchment environmental services: A Negotiation Support System

[3] Minhas, P.S. and Samra, J.S. (2004). Wastewater Use in Peri-urban Agriculture: Impacts and Opportunities. Bulletin No. 2, CSSRI, Karnal 132001, India.

[4] Mishra. S.M. (2006) Impact of the rural catchment on the Bhoj wetland and options for mitigation.Interim report, Lake Conservation Authority of Madhya Pradesh, Bhopal.

[5] Sachdeva,S. (2009). Integrated Lake Basin Management and Conservation Issues

[6] ofBhoj Wetland available on wldb.ilec.or.jp/data/ilec/WLC13_Papers/S8/s8-4.pdf

[7] Shrivastava,P. andJoshi,G.H. , (1992). Status Report of Upper Lake of Bhopal, Submitted to EPCO

[8] Shrivastava,P. Joshi, G.H. Vyas, V and Swarup, A. (1994). Observations on the Management of A Tropical Wetland Ecosystem, J. Hydrobiol.Vol.X, No. 1. 15-28

[9] Strauss, M. and Blumenthal, U. (1990). Human Waste Use in agriculture and Aquaculture: Utilization Practice and Health Perspectives. IRCWD Report 09/90. International Reference Centre for Waste Disposal, Duebendorf, Germany.

[10] Transition to water sensitive urban design. The story of Melbourne Australia. Report 07/1. by Rebekah Brown and Jodi Clark. June 2007.School of Geography and Environmental Science,Monash University

[11] Upadhyay, R. Pandey, K. Upadhyay, S.K. and Bajpai, A. (2012) . Annual Sedimentation Yield and Sediment Characteristics of Upper Lake, Bhopal, India Vol. 2(2), 65-74, .Res.J.Chem.Sci

[12] Valecha, V. Vyas, V. and Valecha, R. (1995). Rehabilitation of The Twin Lakes of Bhopal, In Ecology and Pollution of Indian Lakes and Reservoirs Ed.P K MishaPp 93-97.

[13] Vyas,V. Saxena,S. and Shrivastava,P. (2009). Conservation and Management of Bhoj Wetland (Upper Lake) of Bhopal, India,With Reference To Integrated Lake Basin Management.

[14] 2wldb.ilec.or.jp/data/ilec/WLC13_Papers/S17/s17-17.pdf

★★★