WATER QUALITY OF SMALL JABALPUR LAKES: A CASE STUDY

Sanjay Tignath
Dept. of Geology and Geohydrology, Govt,Autonomous Science College, Jabalpur (M.P.)
(E-mail: tignathsanjay@rediffmail.com)

Medha Jha
Dept. of Civil Engg., Institute of Technology, Banaras Hindu University, Varanasi (U.P.)
(E-mail: bhumedha75@yahoo.co.in)

S.K. Mishra and U.C. Chaube
Dept. of WRDM, Indian Institute of Technology, Roorkee (Uttaranchal) - 247 667
(E-mail: skm61fwt@iitr.ernet.in)

ABSTRACT

This paper presents the study of water quality cycle of small lakes (or tanks) of Jabalpur region in Madhya Pradesh (India) and consequent pollution hazards. These tanks were initially in use for meeting various human demands. However, the encroachment due to urban and industrial growth led to their diminishing. Some vanished completely and the ones sustained became the dumping sites for city waste in recent times. An analysis of surface water quality of the above tanks shows significant changes in its both physical and chemical parameters. Yet, the observed cyclic recovery indicates (i) absorption of the impurity fraction by the lithologic formation below; or (ii) removal of the excessive impurity fraction from water by chemical reactions and/or conversions, but changing the overall chemistry of the system; and/or (iii) transport of the excessive fraction to adjacent groundwater regime. The tract of small lakes along the structural contact between the Granites and the Gondwana shales/clays associated with the wells shows relatively high concentration of the Fluoride and Iron ions. The DRASTIC analysis for pollution potentiality of groundwater due to polluted water bodies leads to characterization of whole surface-subsurface water continuum to be highly prone to induced pollution in future.

INTRODUCTION

Jabalpur city of Madhya Pradesh is situated on and around a geomorphological setup which offered formation of a large shallow wetland in the recent past whose water surface either extended over the ground surface on the Gondwana clays or remained very close to the ground surface wherever continued beneath it. Hence it appeared as if it was a place of fifty two lakes, but in fact it represented one continuous wetland lying between the Granitic hills or even extending beyond the Granites up to alluviums in the north and north-west. The geomorphology-geology interface has hindered development of well organized network of natural drainage system leading to natural water-logging conditions in the lower tracts. This shallow wetland was indeed of no use to growing population on this place, and therefore, the stretch of wetland was gradually converted into several tanks by raising embankments at suitable sites in the wetland in the recent history. These tanks which originally counted over fifty in number were however encroached for lands to develop colonies, parks, civic centers, sports complex etc. and consequently their number and dimensions were largely reduced.

CONTROLS ON WETLANDS

It is necessary to first understand the impact of geomorphology, lithology, and structures to evaluate the danger of pollution of the water regime in and around these tanks if human interference continues to take place. Fig.1 shows geological setup and controls on these lakes converted into tanks.

The geomorphology of the area is basically responsible for the wetland development in the lowland of Gondwana argillaceous facies which falls between the two major barriers of outcrops of the Madan mahal granites, one hilly in the south and the other gentle high in the central-eastern part of the city. The Granite-Gondwana contact is occupied by a series of lakes along the base of the slopes of the Granite hills. Within the granitic outcrops, pools of regolith occupied by relatively high set ponds in the Granite hills have developed (Fig. 1).

Wetlands in the low-lying areas of the Granite-Gondwana contact extend towards the west and north-west on clay settings of the Gondwana supergroup (Fig. 1). The clays exhibit lateral and vertical transition into silty-clays and silty-sand facies. The clays (forming lensoid bodies) modify the ground water table which is less than 1.8 m in depth in Amanpur-Garha belt associated closely with the lakes at the Granite-Gondwana contact. These wetlands occupy older alluviums in the further westward and northward areas (Fig. 1).The ponds/lakes are distributed over different lithologies as given below:

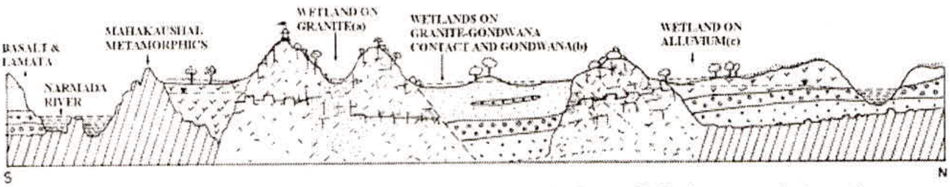

Fig.1 Relationship of wetlands with geomorphology, lithology and structures

Wetlands of the regolithic pools of relatively high granitic terrains.

- Wetlands of the Gondwana terrain
    - Gondwana (clays)- Granite contact belt
    - Gondwana (Jabalpur shales and clays) rocks terrain
- Wetlands of alluvium terrain

ANALYSES OF WATER SAMPLES COLLECTED FROM VARIOUS TALS AND WELLS

It was aimed that the analyses of the quality of water of the tanks would not mean anything until the quality of the groundwater around the tanks is also studied, as the tanks are only surficial manifestation of the continuous wetland(Coates, D.R., 1985) in the study area. Therefore, this work contains the quality analysis of water of the tanks as well as of the wells in the vicinity of the tanks.

The tanks receive water of run-off from the slopes of the adjoining highs and do not have any outlets except in the case of Jabalpur talab which has radial centripetal drainage pattern and only one stream drains the water away. Thus the extraction of water from the tanks takes place only through evaporation and infiltration to the ground water whose water table normally quaquaversally dips away from the base of the tanks. It leads to surmise that the veneer of sediments on the floor of the tanks takes active part in the process of quality maintenance, which in turn, is adjusted to the cyclic seasonal input. The characteristic sediment profiles of the veneering layer are described below:

(i) The regolithic wetlands within the granitic highland exhibit a rugged profile. The upper layer is of unsorted grains of quartz and feldspars sub-rounded to sub-angular in shape and ranging in size from coarse sand to pebbly. The lower layer is greyish-brown and comprises of fine grained sand. The third layer is greenish-yellow and muddy in nature, while the fourth one is weathered and leached granitic material.

(ii) The wetlands of contact area (located in the fault zone) are mixture of sand and clay. The clayey setup belongs to the Gondwana clay formation in the north, and sand to granite hills. The log represents greater muddy fraction and decayed phytoplanktons with very low dissolved oxygen (less than 1mg/liter), leading to development of anaerobic conditions.

Samples were collected from the various Tals such as Hanumantal, Devtal and Soopatal. The Hanumantal is on relatively flat country of granites, whereas the Devtal and Soopatal are immediately down the slopes of Madanmahal hills. The Devtal, again, solely occupies the Granites but the Soopatal is partially located on Granites and Gondwana rocks. The results of the quality analysis of Hanumantal are also given in the Table 1, as representative of the cyclic recovery of quality parameters. Outcome of the analysis of these ponds shows that the temperature variation of the water sample is between 21°C to 27°C. The water of Hanumantal is not turbid. Thus its turbidity does not interfere with the recreational use and aesthetic enjoyment of the water, whereas the water of Devtal and Soopatal has more turbidity, which might be owing to the higher concentration of suspended solids in it (NAS 1974) carried in by direct run-off from the adjoining torred slopes of the granitic hills to these tanks. Thus this water is dangerous for swimming purposes. The settled materials also blanket the bottom of water bodies, damage the invertebrate population, block spawning gravel beds, and if organic, remove dissolved oxygen from overlying waters (EIFAC, 1965; Edberg and Hofsten, 1973). The various other parameters such as pH, chloride content, sulphates and phosphates, total hardness, nitrate contents are within the acceptable limits. The total dissolved contents vary from 200mg/litre to 700mg/lit which might be due to the excessive evaporation during the month of May or due to the influx of waste disposal which thereby increases the specific conductivity of the water. An analysis of surface water quality of the above tanks shows significant changes in its both physical and chemical parameters. Yet, the observed cyclic recovery indicates (i) absorption of the impurity fraction by the lithologic formation below; or (ii) removal of the excessive impurity fraction from water by chemical reactions and/or conversions, but changing the overall chemistry of the system; and/or (iii) transport of the excessive fraction to adjacent groundwater regime. The wells associated with the tract of small lakes along the structural contact between the Granites and the Gondwana shales/clays show relatively high concentration of the Fluoride and Iron ions.

To understand the impact of these water bodies on the quality of groundwater, samples of water of various hand pumps in the vicinity of the tanks of the city were collected for two consecutive years and were analyzed in the laboratories. The results of these samples from the wells in the vicinity of Granite-Gondwana contact wetlands are represented in the Table 2. The results show that the PH, chloride content, total hardness, total dissolved solids, sulphates, sodium, potassium contents, dissolved oxygen in these water samples are within the acceptable limit. For the whole of the year the turbidity of water was within the safe limit but however, during the rainy reason the turbidity of water increased which might be due to increase in the concentration of total solids (Gammon, 1970). Thus, this water has to be purified before using it for drinking purposes by treating with alum or by boiling.

Table 1. Quality parameters and their cyclic recovery for Hanumantal

S. N.	Month	Hanumantal				
		Jan.2003	May. 2003	Sept. 2003	Jan. 2004	May.2004
1.	Temperature	21°	29°	24°	21°	28°
2.	Turbidity	greenish	greenish	greenish	greenish	greenish
3.	Odour	Odourless	Odourless	Odourless	Odourless	Odourless
4.	PH	7.5	7.5	7.4	7.4	7.5
5.	Specific conduct.					
6.	Choride	50.00	52.00	57.65	64.07	64.97
7.	Total alkalinity	190.00	230.00	220.0	190.0	240.0
8.	Total hardness	170.00	200.00	190.0	210.0	200.0
9.	Calcium hardness	150.00	160.00	130.0	170.0	160.0
10.	Mangnesium hardness	20.00	40.00	60.0	40.0	40.0
11.	Total solids	405.00	640.00	260.0	341.0	880.0
12.	Dissolved solids	315.00	500.00	200.0	288.0	700.0
13.	Suspended solids	90.00	140.00	60.0	53.0	180.0
14.	Amm. Nitrogen	0.48	0.6	0.22	0.65	0.62
15.	Nitrite nitrogen	0.052	0.055	0.2	0.32	0.50
16.	Nitrate nitrogen	0.30	0.003	0.04	0.30	0.44
17.	B.O.D.(3 days 27°C)	2.8	2.8	2.5	2.7	2.9
18.	C.O.D.	24.0	44.0	48.0	24.0	48.0
19.	Phosphate	0.06	0.06	0.05	0.003	0.06
20.	Sulphate	5.0	5.0	4.0	4.0	5.0
21.	Total coliform	Nil	Nil	Nil	Nil	Nil
22.	Faecalcoliform	Nil	Nil	Nil	Nil	Nil
		D/O_2= 2.0	D/O_2= 2.0	D/O_2= 2.0	D/O_2= 2.0	D/O_2= 2.0

As the sampled hand pumps are located in the vicinity of the tanks, the domestic garbage and sewage materials that are continuously dumped in periphery of these tanks can also contaminate the water of these hand pumps. It is due to this reason, that non faecal type of coliform bacteria have been reported from hand pumps located at Amanpur and Garha (Table 2).

Besides these hand pumps, water samples were also collected from various partially or wholly reclaimed wetlands, converted into residential colonies such as Gupteshwar, Madanmahal, Rani Durgawati ward, Tripuri ward, Kasturbagandhi ward, Nehru ward, Arvindward, Sheetlamai ward, Chandrashekhar ward and Upratinganj ward . The excess of fluoride in the drinking water has been reported in these areas (P.H.E. department Jabalpur, Table 3). The excess of fluoride in these areas may be due to the presence of tourmaline and/or apatite in the Granites of the adjacent regions as these hand pumps are invariably associated with the localities, which are immediately downslope from tourmaline bearing Granites. The contamination of the drinking water with fluorides has resulted in the endemic flourosis in these areas, which has manifested into dental and skeletal fluorosis in human beings.

Table 2. Average water quality of wells in the vicinity of Granite-Gondwana contact wetlands

S. N.	Parameter	Average quality of wells qround Amanpur- Garha tract					
		July 2003	Nov. 2003	Jan. 2004	May 2004	July 2004	Nov. 2004
1	Temperature	23°	23°	21°	29°	23°	23°
2	Turbidity	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
3	Odour	Odourless	Odourless	Odourless	Odourless	Odourless.	Odourless
4	pH	7.4	7.4	7.15	7.4	7.4	7.4
5	Specific conductivity		193.00	234.00	-		193.00
6	Choride	25.00	29.0	12.49	39.98	27.00	28.0
7	Total alkalinity	190.00	190.0	10.00	210.00	200.00	170.0
8	Total hardness	150.00	240.0	335.00	190.00	163.00	252.0
9	Calcium hardness	120.00	170.0	220.00	140.00	130.00	180.0
10	Magnesium hardness	30.00	70.0	105.00	50.00	33.00	72.0
11	Total solids	185.00	210.0	258.00	290.00	189.00	228.0
12	Dissolved solids	102.00	150.0	220.00	210.90	104.00	150.0
13	Suspended solids	83.00	60.0	38.00	80.00	86.00	78.0
14	Amm. Nitrogen	N.D	N.D	N.D	N.D	N.D	N.D
15	Nitrite nitrogen	N D	N D	N D	N.D	N D	N D
16	Nitrate nitrogen	N D	N D	N D	N.D	N D	N D
17	B.O.D.(3 days27°C)	1.4	3.5	2.0	2.7	1.8	3.5
18	C.O.D.	24.00	24.0	12.00	20.00	24.00	22.0
19	Phosphate	-	-	-	-	-	-
20	Sulphate	0.003	0.003	0.003	0.003	0.003	0.002
21	Total coliform	Nil	Nil	Detected	Detected	Nil	Nil
22	Faecalcoliform	Nil	Nil	Nil	Nil	Nil	Nil
		D/O_2 =7.4	D/O_2=7.5	D/O_2=7.4	D/O_2=7.2	D/O_2=7.2	D/O_2=7.8

Water samples collected from few hand pumps located in the vicinity existing or extinct ponds at Shankarshah ward, Gupteshwar, Jawaharnagar, Cantt, Madanmahal, Sheetlamai, Sarafa, Milloniganj (Table 4) area have been found to have excess of iron in water. One of the reasons for this excess of iron appears, as is very often true, but not confirmed in the present case, to be the corrosion of the tube wells and water supply installation. This also encourages growth of various bacteria. Iron is an objectionable constituent in water supplies for either domestic or industrial use. Iron appreciably affects the taste of beverages (Riddick, et al, 1958) and can stain laundered clothes and plumbing fixtures. Noticeably, these are all very old hand pumps. It also creates an aesthetic problem because of the taste and odour which it lends to the water.

Table: 3 Localities of excess of fluoride in the study area

S.N	Ward name	places	Hand pumps/ Tubewells
1	Gupteshwar ward	Hathital	
2	Madan Mahal ward	Supatal Hanuman mandir	Hand pump
3	Rani Durgawati ward	In front of Mahendra showroom	Hand pump
4	Tripuri ward	In front of Munnalal's house	Hand pump
5	Tripuri ward	Kohni Nagar Nigam Chouki	Hand pump
6	Rajiv Gandhi ward	Miloni ganj gohalpur Road	Hand pump
7	Kasturba Gandhi ward	Aga chowk Masjid	Hand pump
8	Dayanand Saraswati ward		Hand pump
9	Dayanand Saraswati ward	Russel Chowk bus stand	Hand pump
10	Dayanand Saraswati ward	Bhanwar tal park	Tube well
11	Dayanand Saraswati ward	Bhanwar tal park	Hand pump
12	Tripuri ward	Medical college H.No 2	Hand pump
13	Tripuri ward	Medical college gateNo.1	Hand pump
14	Tripuri ward	Medical college gate No2	Hand pump
15	Madan Mahal	Supatal Badrinagar	Hand pump
16	Nehru ward	Beoharbag school	Hand pump
17	Arvind ward	Ghamapur chowk	Hand pump
18	Seetlamai ward	Tulsi mohalla	Hand pump
19	Seetlamai ward	Ram Krishna colony	Hand pump
20	Seetlamai ward	Govt. women polytechnic college	Hand pump
21	Seetlamai ward	Benjamin ka bada	Hand pump
22	Chandra Shekhar ward	Alok Bharti Vidhayalaya	Hand pump
23	Upraingan j ward	In front of Manulal hospital	Hand pump
24	Upraingan j ward	Near Santoshi pan bhandar	Hand pump
25	Upraingan j ward	Shiv mandir Natbaba gali	well

Table 4. Localities of excess of iron in the study area

S.N	Ward	Place	Hand pump/ Tube well
1	Shanker Shah ward	In front of Hanuman mandir	Hand pump
2	Shanker Shah ward	In front of Jagdish Baghel House	Hand pump
3	Shanker Shah ward	Near Shiv Mandir Rajesh General Store	Hand pump
4	Banarsi Das Bhanot ward	In front of Vishal province store	Hand pump
5	Gupteshwar ward	Hathital	Hand pump
6	Rani Durgawati ward	In front of Mahendra showroom	Hand pump
7	Jawahar nagar	Near Shani general store	Tube well
8	Cantt.	Plot No. 96 near railway 3 bridge	Tube well
9	Cantt.	Plot No. 98 near railway 3 bridge	Tube well
10	Madan Mahal ward	Supatal Bajrang nagar main road	Tube well
11	Nehru ward	Beoharbag school main road	Tube well
12	Sheetala Mai ward	Tulsi mohalla	Tube well
13	Sheetala Mai ward	Govt. women polytechnic college	Tube well
14	Cantt.	Karondi near Rajendra Yadav's house	Tube well
15	Cantt.	Rajkumar Yadav's house	Tube well
16	Sarafa	Pan Dariba	Tube well
17	Sarafa	Harsh ki puliya Dixitpura	Tube well
18	Mahatama Gandhi ward	Rathi colony.	Tube well
19	Miloni Ganj ward	Badhaya mohalla	Open well
20	Miloni Ganj ward	Ballu Ustad's hous	Open well

The association of the Iron or fluoride contaminated wells with the general tract of the Gondwana-Granite contact wetlands belt needs detailed study to establish if the association is a result of wetland-aquifer interface interactions leading to a contribution from the mineralogy of the lithological members characteristic to this peculiar hydrogeological environment under anthropogenic stress.

Water quality has been assessed using environment–media index. There are numerous water quality indices, which have been developed over the last 25 years. The one followed in this work is water quality index (WQI) developed in 1970 by the U.S. National Sanitation Foundation (NSF). The reason for selecting this relatively older method is its simplicity; also, there are no reference reports published for the study area and therefore this work provides a base-line data in the simplest manner. More specialized work using specific indices will definitely find these results guiding and useful, at least, in the preliminary sense.To calculate the aggregate WQI, a weighted linear sum of the indices WQI_a was calculated. These are expressed mathematically as follows (Ott, 1978):

$$\text{NSF } WQI_a = \sum_{i=1}^{n} w_i I_i \qquad (1)$$

where w_i = importance weights assigned to variables and I_i = sub index values. the value of w_i for various variables are given in the standard tables as may be found in any standard reference (Ott, 1978). The quality of water and the color suggested according to NSF WQI is (Ott, 1978, p.212) as, Very bad, (WQI=0-25), Red; Bad, (WQI=26-50), Orange; Medium, (WQI=51-70), Yellow; Good, (WQI=71-90), Green; and Excellent, (WQI=91-100), blue. WQI for Hanumantal, Soopatal and Devtal was found to range between 26-50, and thus water is of bad quality and the color is orange. This water can be used for irrigation purpose.

Besides the above, a DRASTIC analysis for pollution potentiality of groundwater due to polluted water bodies leads to characterization of whole surface-subsurface water continuum to be highly prone to induced pollution in future, particularly in reclaimed areas with new constructions. The water table in these areas being very close to the ground surface falls, at most of the sites, within such depths as of shallow septic tanks, a serious concern to pollution hazards. The acronym "DRASTIC" is derived from the seven factors in the rating scheme. D = Depth to Ground water, R = Recharge rate, A = Aquifer media, S = Soil media, T = Topography (slope), I = Impact of the vadose zone, C = Conductivity (Hydraulic) of aquifer.

Determination of the "DRASTIC" index for a given area involves multiplying each factor weight by its point rating and summing the total. The higher sum values represent greater aquifer vulnerability. For a given area being evaluated, each factor is related on a scale of 1 to 10, indicating the relative pollution potential of the given factor for that area. Once all factor have been assigned a rating, each rating is multiplied by the assigned weight, and the resultant numbers are summed as follows: -

$$D_rD_w + R_rR_w + A_rA_w + S_rS_w + T_rT_w + I_rI_w + C_rC_w = \text{Pollution potential} \qquad (2)$$

where r = Rating for area being evaluated and w = importance weight for factor. Weight values from 1 to 5 expressed the relative importance of the factors with respect to each other. Rating are obtained from tables or graphs for each factor, while the importance weights can be found in the generic "DRASTIC" tables.

The assessment of potential of pollution for the subsurface water regime of the area reveals that the area is nearly 70% prone to pollution. This impact assessment study now becomes very significant in the light of the above discussion. Careless development might render the groundwater permanently polluted.

CONCLUSIONS

This study shows that the surface water of the tanks is contaminated. The various parameters or indices, which serve the purpose of assessing impact, indicate that the human interaction can certainly deteriorate the quality of water. It is, however, noticeable that most of the wells of rural areas are still free from contamination. However, it is widely realized fact that it is very difficult to use the words "free from contamination". The natural system has a capability to purify and sustain its original parameter and this process leads to the misconception of categorizing water as "free from contamination". In fact, the iterative impacts would not be noticeable till the bifurcation point in the behaviour of the natural system is reached. Once the bifurcation is reached, the system ceases to behave in the manner it has been behaving, in order to purify the water in the present case; rather it would show the effects of iterative contamination all of a sudden afterwards. This is often overlooked until the samples show values within the normal range.

ACKNOWLEDGEMENT

The first author is thankful to the UGC Delhi for funding the Post Doctoral research project to him and to the Dept. of WRD&M and Dept. of Earth Sciences, IIT, Roorkee for providing the facilities to conduct the research work.

REFERENCES

Coates, D.R. (1985)., "Wetlands, water problems, geology and society," A Dowden and Culver book.

Edberg, N., and Hofsten, B.V. (1973), "Oxygen uptake of bottom sediment studied in- situ and in the laboratory". Water research, 7: 1285.

European Inland Fisheries Advisory Commission. (EIFAC) (1965), "Water quality criteria for European freshwater fish; report on finely divided solids and inland fisheries". Int. Jour. air water poll. 9:151.

Gammon, J.R. (1970), "The effect of inorganic sediment on stream biota. Water poll. Cont. Res. Series, 18050 DWC 12/70, U.S. Environmental Protection Agency". U.S. Government printing office, Washington, D.C.

National Academy of Sciences (NAS) National Academy of engineering, (1974), Water quality criteria, 1972. U.S. Government Printing office, Washington, D.C.

Ott, W.R. (1978), "Enviornmental Indices, Theory and practice", Ann Arbor,Science Publishers, Ann Arbor,Mich., pp 2,5,135-169,202-213.

Riddick, T. M . (1958), "Iron and manganese in water supplies". Jour. Amer. Water works Assn. 50: 688.