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Water Quality Assessment and Feasibility of River Bank Filtration for Water Treatment – A Case Study

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***Abstract*—In a fast developing country like India, there are many challenges for providing good quality and safe water supply. One of the major impediment in achieving the safe drinking water supply in India is the growing population and implementation of new/emerging technologies. The increasing waste generation and non-availability of proper dumping sites in many of the cities resulted in unscientific disposal of both solid and liquid wastes. Consequently many major river flowing in and around the city area have turned in to waste water streams. If this trend continues, the cities will face a major hurdle in supplying good quality water to the public. In the present research, an effort has been made to understand the impact of sewage and industrial waste waters draining into the fresh water stream and possible solution to overcome such impact through river bank filtration techniques. A case study has been conducted in Belgaum city in Karnataka (the second capital of Karnataka). Belgaum city drains all its waste water into Bellary nala which passes through the fertile agriculture belt of Belgaum city. Water samples were collected from selected locations from the polluted stream and also from the adjoining ground water wells. Various physical, chemical and biological parameters were analysed and found that the water quality of waste water is significantly deteriorated where as the ground water in the riparean zones are quite good without any external treatment. An attempt was made to understand the interaction between the stream and the adjoining aquifer using Processing MODFLOW software. The model result shows that there is large seepage of stream water into the groundwater aquifer. However, the ground water quality analysis carried out shows that there is no significant degradation in water quality of the adjoining aquifers. The possible explanation can be that as the water passes through thick zone of black clayey soils before entering into the aquifers, most of chemical and biological contaminants get absorbed and only good quality water enters into the aquifers. This natural process of bank filtration can be used to purify the polluted surface water and the good quality water can be used for both agriculture and domestic purposes. Therefore it is recommended to construct open wells to draw good quality water from the stream and use it for agriculture purposes. Direct use of polluted water for agriculture should be discouraged, as in long run it may affect the agriculture growth as well as human and animal health.**

Key word: Riverbank filtration, Groundwater, Water quality, Modeling

I. INTRODUCTION

One of the greatest challenges facing India today is the growing number of rural and urban households who need access to basic infrastructure, mainly water supply and sewage. If lacking, this can have a significant adverse impact on human health, productivity and the quality of life. In India, the supply of safe drinking water is not an issue as far as the technology is concerned. Rather, it is due to the fact that stakeholders are largely unaware of the available alternatives and the complexity of the suitability of one technology over the other applicable alternatives in their situation. Therefore, the major challenge before us is the selection of the appropriate technology considering the multifaceted issues including technical feasibility, affordability, customs and practices, preferences, and available institutional support. The potential goal is, presenting no single and absolute solution, but offering a comparative analysis of various options, and encouraging the decision makers and communities to adopt the one that is best suited to their needs [1]. In the recent years, one of the most accepted and widely used techniques in the Western and European countries are River Bank Filtration (RBF) methods.

Riverbank filtration (RBF) operates by extracting water from wells located near rivers (20 to 200 meters), where the river water is induced to flow through riverbed or riverbank soils to a single well or gallery of wells. Depending on effectiveness of the combined physical, chemical and biological processes, riverbank filtration has been reported in the literature to provide complete removal of suspended particles, dissolved contaminants including organic compounds and most pathogenic microorganisms. The concept of riverbank filtration for water purification began in Germany in the 1870s but was not utilized to any extent in the United States until 1960s. Many refinements have been noticed with these systems since that time. With increased concern for surface water pollution and water utilities seeking higher quality source water, there is a growing interest in riverbank or other stream bank filtration versus taking water directly from the flowing stream. In RBF (which is somewhat similar to slow-sand filtration), river water contaminants are attenuated from a combination of processes such as filtration, microbial degradation, sorption to sediments and aquifer sand, and dilution with background groundwater. According to previous published work by numerous researchers, RBF has proven its effectiveness in water treatment [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]. Reported data indicated that RBF can effectively remove most of the major and micro-pollutants including particulates, colloids, algae, organic and inorganic compounds, microcystins, pathogens and even heavy metals [11]. Furthermore, bank filtration is able to attenuate concentration or temperature peaks and can provide protection against shock loads. Compared to traditional water treatment plants, RBF could have more advantages especially in improving the removal capacity and reducing the total cost. In addition, RBF reduces the concentrations of disinfection by-products due to its ability to remove organic matter. There is no waste generated from RBF which gives it an environmental advantage over other methods.

Based on the available background information, in the present study an attempt has been made to assess the water quality of a waste water stream (Bellary nala, Belgaum, Karnataka, India) and adjoining aquifers to understand the impact of waste water stream on ground water of the riparian area. Ground water flow was studied using Processing MODFLOW to signify the interaction between surface and ground water. The main objective of the study is to address the feasibility of RBF to tackle the water quality problems in areas covered by black soils, particularly in peninsular parts of India.

II. STUDY AREA

Belgaum which is one of the important cities of Karnataka, located between longitude 74°30′ E to 74°40′ E and latitude 15°45′ N to 15°57′ N (Fig. 1). The city area is divided into 3 river catchments namely Bellary nala (53.35%), Markandeya river catchment (31.65%) and Mongetri Nala catchment (14.98%). Belgaum municipality was established in the year 1951 and in 1977 it was given the status of Municipal Corporation. The population of the city is more than 6 lakhs including cantonment population. The city gets its water supply from Rakkaskop barrage across Markandeya river located at about 25 km west of Belgaum city. The area falls under semi-arid climate with an average annual normal rainfall of 1324 mm. Ninety five per cent (95%) of the annual rainfall is received during June to October through south-west monsoon.

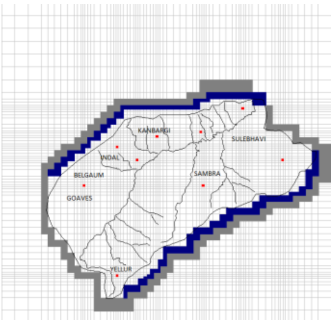

Figure 1. Bellary nala catchment map with observation well locations

The Belgaum city generates a sizable amount of liquid and solid waste. The solid waste amounts to about 120 tonnes per day. There are 2 waste disposal sites in the Belgaum city. The most damaging waste in the Belgaum city is in the form of sewage. There are no sewage treatment plants and recycling facilities within the city area. The entire sewage is directed to Bellary nala through gutters and sewer lines. The Bellary nala, once perennial stream carrying fresh water has now turned into a sewer drain all along its course of about 30 km. Nala passes through a highly fertile black soil that is underlain by porous rocks. Probably by now this fresh water aquifer might have been contaminated with the influx of sewage. The farmers along this nala pump out the sewage water for irrigating sugarcane, paddy, vegetable etc., thereby passing the toxic contaminants into the food chain.

A. Geology and Soils

The catchment of Bellary nala is in the form of depression with elevated portions on north, west and south. Fig. 2 represents the geology across the study area. The eastern part is open. Fig. 3 shows the distribution of soils in the catchment. The major part of the study area is covered with deep black soil and mixed black sols. Laterites and weathered basalt are the only litho units that are water bearing.

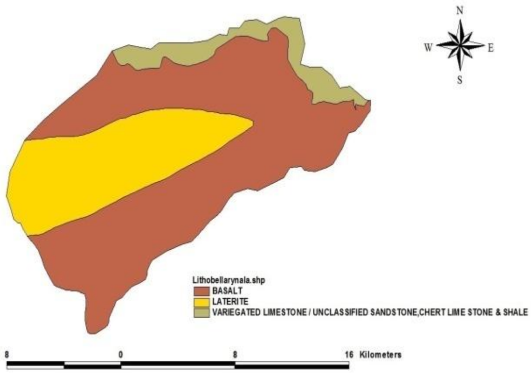

Fig. 2: Geological map of the Study area

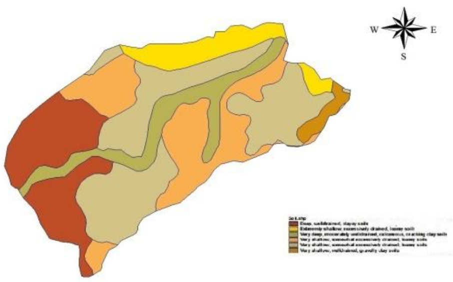

Fig. 3 Soil map of Bellary nala catchment

III. MATERIALS AND METHODS

The purpose of the current investigation is to present the technical applicability of river bank filtration technique for the treatment of waste water. For this purpose, previous reported data and current measurements for Bellary nala water and groundwater were conducted. In addition, the city area between Damne and Sulebhavi was investigated for RBF applicability to treat the waste water flowing through Bellary nala. In this part, additional measurements were made to supplement the available data. Measurements of flow hydraulics and soils analysis were also carried out.

Temporal and spatial variations of quality parameters were monitored. The physical parameters such as temperature, pH and electrical conductivity were determined in the field at the time of sample collection using portable thermometer, pH meter and water testing kit. Other major anions and cations were determined by using standard methods [12].

Table 1 Observed Water Quality parameters of Bellary nala and Ground water (Pumping wells and percolation wells)

Parameters	Bellary nala		Ground water quality of pumping wells		Ground water quality of percolation wells	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
pH	7.1	9.7	6.50	8.7	6.5	6.9
Elec.conductivity (mmhos/cm)	377	1680	781	2100	75	829
TDS(mg/l)	222	1047	316	1336	44	513
Total Solids	225	3524.0	250	799	119	700
Total Alkalinity	16.3	300	80	358	32	226
Chlorides	53.7	1489.3	21.84	238.29	69.5	158.86
Fluoride	0.08	1.27	0.05	0.85	0.05	0.80
Sulphates	10	142	49	127	12.0	95.0
Total Hardness	80	400	96	423	60.0	380.0
Calcium	5	93.00	164	294	21	59
Magnesium	0	17.10	68	88.0	11	29
Potassium	4	180	0.85	28.0	6	17.1
Sodium	53	630	84	168.3	9.20	117.0
Iron	2.4	5.4	0.88	2.32	0.11	0.32
Oil &Grease	20	400	0	36.0	0	16.5
COD	22	580	18	27.0	11	23.0
DO	0	5.8	4.5	5.7	3.4	6.2
BOD	1.6	380	1.29	60.2	0.8	1.1
E. Coli counts	2000	160000	500	20000	2900	4100
F. Coli counts	800	118000	300	12700	1870	2180

IV. RESULTS AND DISCUSSION

A. *Water Quality Investigations*

The water quality status of Bellary nala (a waste water stream flowing through Belgaum city) and also the ground water quality in the adjoining aquifers is shown in Table 1.
The physic-chemical characteristics of Bellary nala water and ground water show significant variation all along the stretch of the stream. Bellary nala water show variations with respect to the discharge of waste water from various point sources where as the ground water quality is dependent on the soil, geology, physical and biological activities of the region.

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Extensive field investigations were carried out during the different seasons and found that all along the stretch of the river, there is a complete deterioration of quality which is indicated by its foul smell and aesthetic conditions. The measurements of temperature observed close to the waste water discharge points are quite high (24° to 30°C) where as in the adjoining aquifers, it varies between 22°C to 26°C. A pH range of 6.5 to 8.5 is normally acceptable as per guidelines suggested by WHO and BIS. In the present study it is noted that the pH value of Bellary nala water varies

between 7.1 and 9.7 and that of ground water lies between 6.5 and 8.7. It is noted that about 15% of surface water were affected by higher pH whereas in the case of ground water it is only 5%. Sixty per cent of the water samples from Bellary nala show very high electrical conductivity (377 -1680 mmhos/cm) and TDS (222 to 1047) which is higher than the permissible limits. However, in the case of ground water only 15% samples are above the permissible limits. Total solids in the surface water varies between 225 mg/L and 3524 mg/L and in the ground water, it ranges from 250mg/L to 799 mg/L. There is a drastic reduction in the percentages of samples affected by Total solids (reduced from 3524 mg/L to 799 mg/L) which reduced from 65% to 10%. In Bellary nala, the total alkalinity and chloride concentration shows wide variations and found to be on higher side in most of the locations (80% of the samples), where as in the ground water, majority of the samples were within the permissible limits, i.e. only about 15% of the samples show higher alkalinity and the chloride concentration in all observation wells is within the permissible limits. Other major anions such as fluorides (reduced to 0.85 mg/L in ground water from 1.27mg/L present in the Bellary nala) and sulphates (from 142 mg/Lto 127 mg/L) show considerable decrease in the ground water. However, it is noticed that the total hardness along with calcium and magnesium concentration show an increase in majority of the locations. This increase is attributed to the calcareous soils and addition of soil amendments applied in various agriculture fields. The higher concentration of potassium and sodium found in the waste water stream show a significant reduction of concentration in the observation wells. Similarly the iron content and oil and grease also show significant reduction in the ground water.

The Chemical Oxygen Demand is found to be very high in Bellary nala. The maximum value of COD is recorded at the discharge point of Lendi Nala (580 mg/L) and a minimum value of COD is recorded at Yellur (22 mg/L), at the upstream point. COD in the ground water varied between 18 mg/L and 27 mg/L. Maximum was observed at Kudchi. The extreme value of COD is an indication of the source of contaminants emanating from various industries located in the catchment of Bellary nala. These industries include small automobile industries, textile industries, electroplating industries and foundries. The permissible limit for COD in inland surface water is 250 mg/L.

Dissolved Oxygen concentration in the wastewater varies between 0 to 5.8 mg/L. 5.8 mg/L is observed at Sulebhavi, due to self purification capacity. However, in all other observation points DO varied between 0 and 1.6 mg/L (Yellur, upstream point of Bellary nala). It is very interesting to note that DO is above 5 mg/L in majority of the wells, except at Halaga and PB Road. BOD5 varied between 1.6 mg/L to 380 mg/L. Lendi nala and sewage waters from Kanbargi area show BOD_5 as 360 mg/L and 380 mg/L respectively. This clearly indicated that the water from the city and extension areas are not subjected to any kind of treatments and discharged directly. BOD_5 of groundwater varied from 1.29 mg/L to 60.2 mg/L. For drinking water BOD should be less than 1 mg/L. The water is considered fairly good up to 3 mg/L of BOD, but when the BOD value reaches 5 mg/L the water is doubtful in purity.

Bacteriological studies conducted in the study area shows a maximum count of 160000 of E.coli and 118000 of F.coli in the Bellary nala water. However, there is a significant reduction in the adjoining wells. In the open wells, close to the nala show a maximum concentration of 20000 of E.coli and 12700 of F.coli. Though the counts are higher than the permissible limits, the percentage of samples affected is only 15% -22%, whereas in the Bellary nala it is 100%.

The above results clearly demonstrated that the water quality problems of these sources vary depending on flow, pattern of use, population density, extent of industrialization, availability of sanitation systems and the socio-economic conditions. Apart from this, Discharge of untreated, or partially treated, industrial and domestic wastewater, leaching of pesticides and residues of fertilizers are often factors that affect the quality of water. In general, ranking pollutants according to their severity to public health and the environment puts pathogenic microorganisms on the top. This is followed by biodegradable organic compounds which deplete dissolved oxygen, affecting water suitability for many purposes.

Pollution load in the Bellary nala has increased due to the increase in various kinds of industries and also due to other human induced activities taking place along the course of the nala. Consequently, quality of Bellary nala water worsened dramatically in the past few years [13, 14]. It is anticipated that the dilution capacity of the nala will diminish due to expansion of agriculture activities and untreated effluents. There are elevated levels of organic matter (measured as COD or BOD_5), heavy metals (Pb, Cr, Hg, and Cd), and fecal coliform.

B. Bellary nala — Aquifer Interaction

The Bellary nala catchment consists of a thick layer of soil underlined by weathered basalts. The transmissivity of the aquifer ranges between 3 and 200m^2/day. The main recharge source is rainfall and also through infiltration from the excess water application for agriculture, seepage from the irrigation canals and sewerage system. Discharge from the aquifer is through seepage to the nala and groundwater extraction through wells. Thus, the main sources of pollution into Bellary nala aquifer are agrochemicals, domestic wastewater, and natural dissolution of soil minerals such as iron and manganese. Ghodichore [15] reported the interaction between surface and ground water in riparian part of Bellary nala catchment using Processing MODFLOW. In the present study model was further refined by monitoring selected wells during 2013-2014, within the close vicinity of Bellary nala (Fig. 4 & 5). Observations showed considerable variation of ground water levels with flow pattern indicating the significant influence of surface water flow on adjoining aquifers. In order to understand the impact of water quality during the process of recharge to ground water, the untreated waste water was allowed to flow to the percolation wells created close to the Bellary nala (about 50m to 150m away from the nala) during the month of October. Water quality analysis was carried out during December and January months. The range of observed quality parameters are shown in Table 1. It is found that the quality of water in the percolation wells show appreciable improvement in comparison to pumping wells which are close to the Bellary nala. To demonstrate the interaction between surface and ground water, Processing MODFLOW was applied [16]. It is noticed that the ground water level in the catchment is comparatively higher than the stream water level. However, in the plain areas of catchment where the agriculture activities are quite intense, due to flooding during the monsoon and also due to excessive pumping in the non-monsoon, water enters the adjoining aquifers there by deteriorating the ground water quality. However, in the percolation wells, the influence is quite negligible due to which the quality shows improvement.

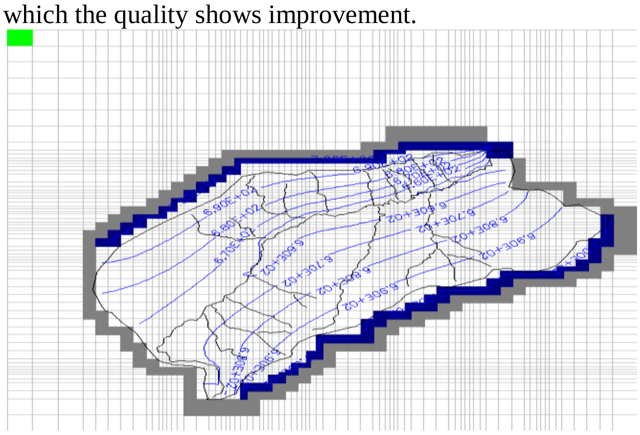

Fig. 4 Simulated Ground water flow in the Bellary nala catchment (without pumping)

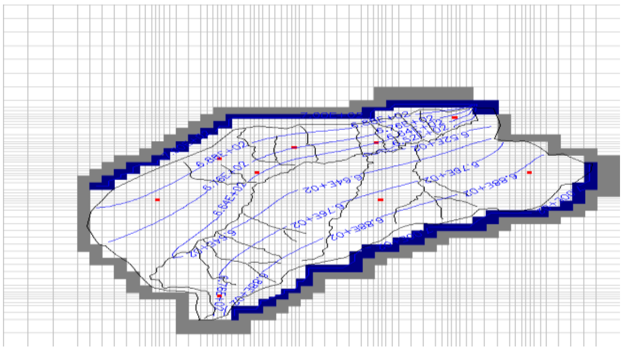

Fig. 5 Simulated Ground water flow in the Bellary nala catchment (with pumping)

Ground water quality observations also indicated that there is large seepage of stream water into the groundwater aquifer due to excessive pumping in certain parts of the Bellary nala catchment. However, the ground water quality parameters observed during the present study clearly demonstrated that quality of water in the adjoining aquifers is quite acceptable for both domestic and irrigation purposes, where as the surface water flowing through the Bellary nala need primary treatment for using it for agriculture purpose. Therefore, the improvement of water quality parameters can be attributed to river bank filtration process which percolates through the thick soil layer. *Bank filtration* is the infiltration of *surface water*, mostly from a *river* system, into a *groundwater* system induced by water abstraction close to the *surface water* e.g. a *river* bank. This water abstraction is commonly done by operating wells. As the water flows through the soil, it is filtered and the quality is improved. In the context of developing or newly-industrialized countries, *BF* may bring relief by replenishing stressed *groundwater* resources with *surface water*, which receives treatment while percolating through the soil and is mixed with the *groundwater aquifer*

V. CONCLUSIONS

At the outset, from the above study it is inferred that the riverbank filtration can be a feasible technique in areas covered by back soil. It is also concluded that the extensive pumping of ground water in the riparian belts will result in water contamination due to interaction of surface and ground water. However, water table recharge and conservation methods will help to maintain the ground water quality for both drinking and domestic purposes. It is further suggested, instead of pumping waste water directly from the stream for agriculture which may in long term affect the water quality. Instead, it is recommended to pass the waste water through soil layers for primary purification so that water contamination can be avoided.

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