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River Bank Filtration in Extreme Environment Conditions

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ABSTRACT: River Bank Filtration (RBF) has been proved to be an efficient water treatment process in European countries, United States as well as in India. Many cities and towns in India are situated on the river bank and have favourable hydrogeological conditions, these can also benefit from River Bank Filtration technology, as RBF is a low cost and efficient water treatment process. Due to a combination of inadequate sewage disposal practices, industrial wastes and mixing of fertilizers and chemicals from non point sources, many river systems have been polluted.

In this work, an attempt has been made to extract water of good quality from a highly polluted river Kali in the state of Uttar Pradesh through RBF. The site was selected near Samli bridge downstream of Kali River at Muzaffar Nagar. The study includes the collection of water samples from the river, a pumping well adjacent to the river and ground water samples near Samli Bus-Stand from March to November' 2006. Two monitoring wells were drilled to study soil characteristics and also to monitor the quality of bank filtrate abstracted. On site field experiments were performed to determine ready to measure water quality parameters, such as pH, dissolved oxygen, specific conductance, water temperature, alkalinity and turbidity on monthly basis. Major cations and anions, and bacteriological indicator parameters were analysed in the laboratory.

The results show that the variation in parameters investigated for pumping well water are within permissible limits for drinking water according to WHO and BIS 10500 (1991). In the filtrate, indicator bacteria such as total coliform and faecal coliform were removed by 98 to 99%, including even under low flow conditions in the river, when the number of total coliform was 93–2400 counts/100 mL of sample, and faecal coliform was 23–70 counts/100 mL of sample. The number of total coliforms in water from pumping wells was observed from 2–28 counts/100 ml of sample and faecal coliform was not detected. Total coliforms were observed at 0–2 counts/100 ml of sample and faecal coliform was not detected in ground water.

The turbidity was reduced by up to 99.7%. The turbidity was observed in the range of 0.26–1.97 NTU in ground water. The dissolved oxygen in river water ranged between 0.0 to 1.05 mg/L. It has been observed that during summer the dissolved oxygen is reduced down to 0.0 mg/L which shows the poor health of the river, while in case of wells it is 0.0 to 1.0 mg/L. Dissolved oxygen was not detected in ground water. The specific conductance of water from the pumping well was observed always higher than that in the river. But the ground water had very high specific conductance value 1788–1990 µS cm^{-1}. The sulphate content in river water has been slightly above in comparison to the well water. The sulfate content in ground water was observed in the range of 99–110 mg/L. Though the total dissolved solids and especially the hardness increase during RBF, they are within permissible limits. The total dissolved solid were observed in the range of 915–995 mg/L, which is above than the permissible value.

It has been observed that the ground water is hard water but the pumping well water was superior in quality. Thus RBF may be helpful in extracting better quality of water in extreme environmental conditions also.

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INTRODUCTION

Good quality water is a basic human need and a precious national asset. Many rivers have been polluted because of our inadequate sewage disposal practices, industrial wastes and mixing of fertilizers and chemicals from nonpoint sources. In riverbank filtration (RBF) process, pollutants present in river water are filtered through the riverbank/bed, helping to obtain a better quality of water through percolation and attenuation. The pumping action through the wells near the river causes the hydraulic head difference between the river water and the aquifer water. Due to the cone of depression, the surface water from the river passes through the porous media of aquifer material and the pathogens and pollutants present in surface water are attenuated. RBF, thus is a natural process of pollutant attenuation. It is a low cost and efficient alternative of water treatment process for drinking water applications. River Bank Filtration has been proved to be an efficient water treatment process in European countries, United States as well as in India.

The two immediate benefits of RBF are the minimised need for adding chemicals like disinfectants and coagulants to surface water to control pathogens and the decreased cost to the community for water treatment without increased risk to human health (Ray *et al.*, 2002a). RBF is considered as an efficient treatment (or pretreatment) mechanism for the removal of various physical, chemical and biological contaminants present in surface water (Price *et al.*, 1999; Prommer *et al.*, 2003; Ray *et al.*, 2002b). Transport of surface water through alluvial aquifers is associated with a number of water quality benefits, including removal of microbes, pesticides, total and dissolved organic carbon (TOC and DOC), nitrate, and other contaminants (Hiscock and Grischek, 2002; Ray *et al.*, 2002a; Kuehn and Mueller, 2000; Doussan *et al.*, 1997; Cosovic *et al.*, 1996; Miettinen *et al.*, 1994). During RBF, surface water is subjected to a combination of physical, chemical, and biological processes such as filtration, dilution, sorption, and biodegradation that can significantly improve the raw water quality (Kuehn and Mueller, 2000; Kivimaki *et al.*, 1998; Stuyfzand, 1998). Pollution loads are extreme in low flow conditions because many of the cities barely treat their sewage and industrial waste prior to discharge. In many countries, RBF is a widely adopted method for water supply e.g., groundwater derived from infiltrating river water provides 50% of potable supplies in the Slovak Republic, 45% in Hungary, 16% in Germany and 5% in the Netherlands (Hiscock and Grischek, 2002). In RBF, various contaminants are reported to decrease. They include the physical parameter like turbidity, chemical parameters like DOC, pesticides, pharmaceutical compounds, nitrates, dissolved ions etc. and decrease in biological contaminants like bacteria, viruses and protozoa etc. RBF acts as a pre-advanced treatment needs in drinking water production and, in some instances, can serve as the final treatment just before disinfection (Ray *et al.*, 2002). The concentrations of anions and cations in river water and riverbank filtrate from vertical as well as horizontal collector wells vary: i.e. depending upon site conditions, well type, location and the contaminant itself (Weiss *et al.*, 2002). RBF has been successfully used for public drinking water supply in Europe over a century and for nearly a half century in United States (Jekel and Grischek, 2003). RBF is found to be useful for removing bacteria, viruses and various contaminants in European conditions and depends on numerous factors including aquifer mineralogy, shape of the aquifer, oxygen and nitrate concentrations in the surface water, types of organic matters in surface and ground water environment and land use in local catchment area and temperature of surface water (Grischek *et al.*, 2005).

The population of India is rapidly increasing and on the other hand water quality is decreasing at many sites. The population of India was nearly 1027 million in 2001 A.D. and it is expected to reach a level of around 1390 million by 2025 A.D. (National Water Policy of India, 2002). Considering the 100 litres of water per person per day the per capita demand of water was 3.75×10^4 million m^3 in 2001 and in 2025 the water demand will be 5.07×10^4 million m^3. Agriculture, the largest consumer of water resources in India, will probably require 770.0 BCM by the year 2025 to support food demand in India. The total estimated demand of 820.7 BCM by the year 2025 would be close to the current available annual utilizable water resource (1100.0 BCM) of India (Vasudevan and Pathak, 2000).

Shamli Bridge is situated in the downstream of Muzaffar Nagar, it carries the entire sewage of Muzaffar Nagar. Being sugar cane as the main crop in that locality, there are many sugar cane industries and all the industrial waste is discharged into River Kali. The River Kali also gets industrial waste from Paper and pulp factory from Saharanpur and Deobund. The river water near Shamli bridge is turned into blackish colour. River Kali is a highly polluted river because it contains very less dissolved oxygen.

RBF is not new in India as many cities and towns are situated near the riverbank and the water supply system in those cities and towns utilizes infiltration wells and galleries to draw the riverbank filtered water. However, there is a need to develop the potential of riverbank filtration in extreme conditions through assessment of water quality at selected RBF sites in India and this happens to be major objective of the present work.

OBJECTIVE

Kali River is one of the most polluted Rivers in Northern India. The objective of this paper is to evaluate the effectiveness of RBF to produce water of high water quality from the Kali River bank near Muzzafar Nagar, Uttar Pradesh.

SELECTION OF SITE

The River Kali traverses a course of 125 km, which lies between 29° 13′ to 30° latitude and 77° 35′ to 77° 45′ longitude, joins River Hindon, a part of the Yamuna river basin in the Indo-Gangetic Plain. The mean rainfall over the basin is 1000 mm and the basin area lies between 276 m to 221 m (masl) with varying slope between 1:50 to 1:100 (Jha et. al. 2005). Due to a combination of faulty sewage disposal practices, industrial wastes and mixing of fertilizers and chemicals from nonpoint sources, River Kali is a highly polluted river. A site for RBF was selected, down stream of Muzaffar Nagar city. The condition of River Kali is shown in Figure 1, the full circle indicates the pumping well of the proposed site. Average width, depth and average discharge velocity of the river was measured on October 2, 2006 were found nearly 25 m, 1.5 m and 0.73 m/sec respectively.

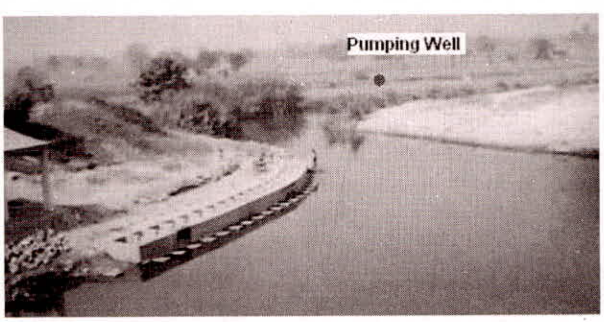

Fig. 1: Selection of site on Riverbank Kali at Muzaffar Nagar

An attempt has been made to observe how water quality improves during RBF in extreme conditions such as that experienced in the Kali River. The schematic view of pumping well and the proposed site for boring piezometers P1 and P2 are shown in Figure 2. The distance of piezometer P1 from pumping well is 6.8 m, the distance of piezometer P2 from P1 is 38.15 m and the distance of River Kali from piezometer P2 is 23.18 m. However, the total distance of pumping well from the River Kali is 68.13 m.

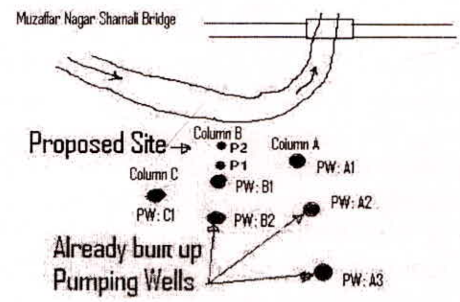

Fig. 2: The schematic view of Pumping Wells

SOIL ANALYSIS

The borings for piezometers P1 and P2 were conducted as shown in Figure 3. The borings were conducted on October 2, 2006 to study the soil characteristics and the variation of the groundwater level.

Fig. 3: Boring of piezometer

The soil samples were collected at every 2 m interval starting from the ground surface and the samples were brought to the Geotechnical Laboratory of I.I.T. Roorkee for further analysis. The particle size analysis was done to observe the soil characteristics. The grain size distribution curve for bored material from the piezometer P1 is shown in Figure 4 and the grain size distribution curve for P2 is shown in Figure 5.

It is observed from Figures 4 and 5 that the top portion up to 0 to 4 m at piezometer P1 and P2 contains clay and silt, the portion of soil between 4m to 8 m is fine sand and below 8 m there is coarse sand and Kankar. The cross-section of piezometer P1 is shown in Figure 6.

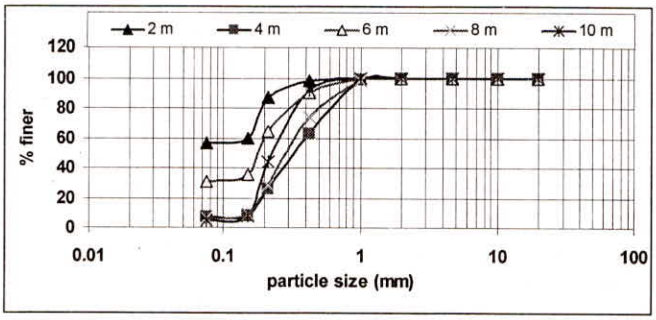

Fig. 4: Grain size distribution curve for piezometer P1

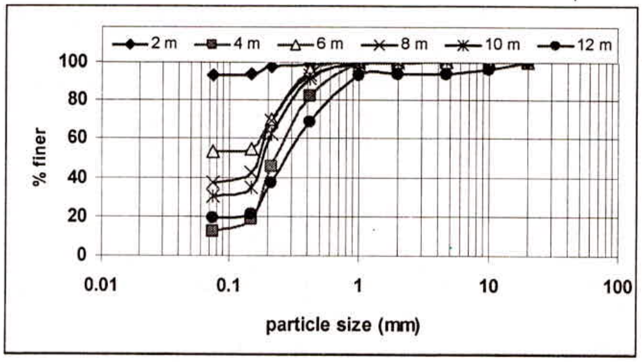

Fig. 5: Grain size distribution curve for piezometer P2

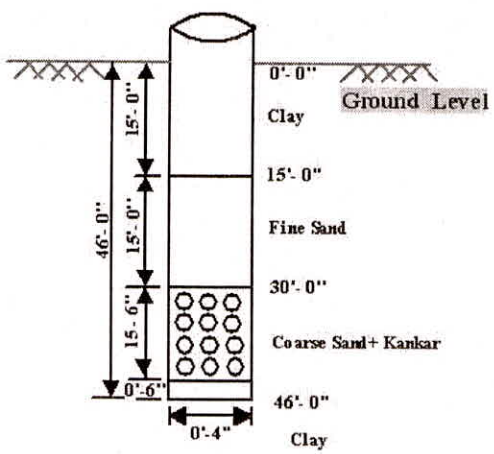

Fig. 6: The details of piezometer P1

SURVEYING OF ELEVATIONS OF MEASUREMENT POINTS

Elevation of the measurement point of the pumping well was measured on October 3, 2006. The elevations of the pumping well, piezometers and the River Kali were determined with respect to a bench mark at Shamli bridge deck level. Levels of various stations are given in Table 1.

The surface water elevation of River Kali as well as the static level of groundwater were observed in piezometers P1 and P2 on October 3, 2006 and are shown in Table 2.

Table 1: Elevations of Measuring Points at the Kali River RBF Site

S. No.	*Leveling station*	*Level masl*
1.	Bridge Deck Level (Bench mark)	240.045
2.	Pumping well level	236.255
3.	Piezometer P1 level	235.580
4.	Piezometer P2 level	235.275
5.	River bed level (Near Pumping Well)	230.820

Table 2: Surface Water and Ground Water Elevations at the Kali River RBF Site

S. No.	*Water Level*	*Level masl*
1.	Surface water in River Kali	231.610
2.	Groundwater level in Piezometer P1	231.030
3.	Groundwater level in Piezometer P2	231.575

GROUND WATER LEVEL

During operation of the RBF well, the groundwater elevation measurement plays an important role in deciding whether the aquifer is recharged by the river or the vice-versa. In the pre monsoon level of the groundwater table is generally lower than that in the post monsoon seasons. The groundwater table observed at Muzaffar Nagar near to the site (Source, Mr. Sudhir Kumar Scientist E1; N.I.H. Roorkee), as shown in Table 3.

Table 3: Observation of Groundwater Table over 10 Years near Muzzafar Nagar

Year	*Pre-monsoon Season (masl)*	*Post-monsoon season (masl)*
1995	231.26	232.54
1996	231.88	234.02
1997	232.83	235.07
1998	233.21	236.87
1999	233.96	234.65
2000	233.3	233.42
2001	Dry (<231)	Dry (<231)
2002	Dry (<231)	Dry (<231)
2003	232.15	233.76
2004	231.68	232.1

In case of operation of the pumping well the water level of the pumping well will further reduce, the level of groundwater can be observed in piezometers P1 and P2.

Collection and Analysis of Routine Water Samples

Water samples were collected every month from March to October 2006. The samples were taken from the pumping well, River Kali and from a hand pump close to Samli bus stand (treated as ground water source). The hand pump is located at a distance of nearly 350 m from the river. Samples were collected and transported as per methods prescribed in Water Quality Standards of India (BIS 10500: 1991).

Analysis of Water Samples

Field parameters such as temperature of water (T_w), dissolved oxygen, specific conductance and pH were measured using a portable WTW 350i meter, with one pH sensor and one combined DO and EC sensor. The measurement location was the same at all times, located about 1 m from the river bank and at a water depth of 0.5 m. Turbidity was measured by a HACH instrument and alkalinity by titration method for the various sites mentioned above. Major anions and cations including bacteriological tests like total coliform and fecal coliform were conducted in the Laboratory of Environmental Engineering of Civil Engineering Department of I.I.T. Roorkee, India as per prescribed methods in Standard Methods (APHA, 2005). The bacteriological tests were conducted in the laboratory of National Institute of Hydrology, Roorkee.

RESULTS AND DISCUSSIONS

Variation in pH

The pH of River Kali water varied from 6.99 to 7.7, the pH of the pumping well water varied from 6.77 to 7.81 and the pH of groundwater varied from 6.84 to 7.29. Monthly variations are shown in Figure 7(A). The pH of River Kali varies in a cyclic order as it depends on the discharge of the river. If discharge is less, pH is higher and vice versa. During monsoon season, the value of pH of pumping well water has increased. All pH values lie within permissible range.

Variation in Dissolved Oxygen (D.O.)

During decomposition of organic compounds D.O. is also utilized thus it is always lower in wells, as shown in Figure 7(B). The variation of D.O. in the River Kali ranges from 0 to 4.01 mg/L. During pre monsoon season the river gets glacier melt water thus has more dissolved oxygen than during monsoon season. The pumping well has more dissolved oxygen during monsoon season. In pre monsoon season and post monsoon season, the D.O. of pumping well water is almost zero. No dissolved oxygen is observed in groundwater.

Variation in Specific Conductance (S.C.)

The value of electric conduction, S.C., concludes with dissolved anion and cation in the water. The S.C. of groundwater is very high varying in the range of 1788 to 1990 μS/cm. The variation of S.C. in the River Kali is between 424 to 599 μS/cm. During pre monsoon season the value of S.C. is higher because of low flow but during the monsoon season, the S.C. has decreased. In the monsoon season, the river water is being diluted due to rain water, discharges are always higher, water gets less contact time with the soil, and thus the value of S.C. is lower in monsoon season. The effect of RBF can be seen from Figure 7(C) that initially the pumping well has less S.C. value but as the river has high S.C. value, the riverbank filtered water takes some time to travel to pumping well. During monsoon the River has a low S.C. value. The value of S.C. varies in a cyclic order ranging from 477 to 550 μS/cm in case of pumping well water. It seems that the pumping well water is directly linked with river water with some travel time and the ground water has got an entirely different value than the River water and infiltrate water.

Variation in Temperature

The temperature of River Kali varies from 14.5°C to 31.8°C as per the season but the temperature of groundwater remains fairly uniform throughout the year. The temperature of pumping well water ranged from 23°C to 29.5°C. It is obvious from Figure 7(D), that pumping well water temperature attains the highest value in September 2006 and again it is having a decreasing trend which is similar to the River Kali water. It seems that the pumping well water temperature has similarity in increasing as well as decreasing trend to the river water according to the gap of travel time.

Variation in Turbidity

In the monsoon season, due to high discharge the River Kali water carries more clay and silt which increase the turbidity. It is distinct from Figure 7(E) that in the monsoon season the river water is more turbid. Due to riverbank filtration turbidity is reduced to a desirable limit. It is important that riverbank filtration plays the key role of a barrier to check the unwanted suspended particles.

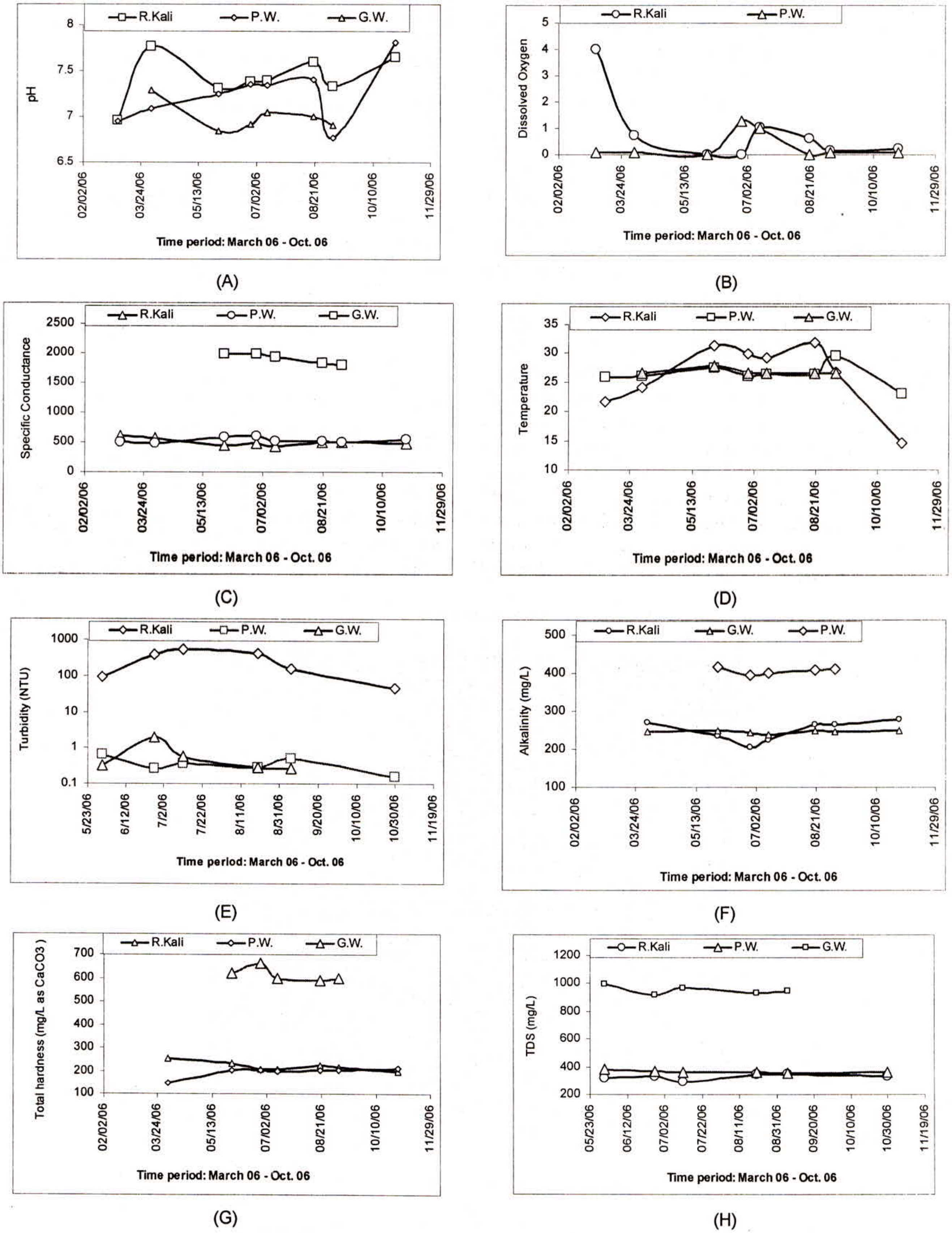

Fig. 7: Variation of Physico-chemical parameters in the River Kali, filtrate and groundwater

Variation in Alkalinity

Alkalinity of water is its acid neutralizing capacity. The groundwater has higher alkalinity ranging between 395 to 415 mg/L because when water passes through the soil matrix, it dissolves carbonates, and bicarbonates. The River Kali water has varying alkalinity from 209 to 275 mg/L but low alkalinity is observed during monsoon season. The alkalinity of the pumping well has rather less variation ranging between 238 to 250 mg/L, as shown in Figure 7(F).

Variation in Total Hardness

In case of groundwater, the total hardness has a very high value in the range of 590 to 660 mg/L. The variation of total hardness in River Kali ranges between 196 to 252 mg/L. In the pre monsoon season total hardness in the river is higher than during monsoon season. It has decreased a bit because of peak flow due to rain water but the variation is very less. The total hardness in pumping well water varies from 146 to 212 mg/L. It is observed from Figure 7(G) that the pumping well water has a distinct relationship with the River Kali water.

Variation in Total Dissolved Solids

The TDS are generally high in groundwater in the range of 915 to 995 mg/L. But in case of River Kali, the TDS vary between 295 to 350 mg/L. In the monsoon season there is a distinct reduction in total dissolved solid. The pumping well has very little variation in total dissolved solids ranging between 355 to 380 mg/L, as shown in Figure 7(H). But the pumping well water has a bit higher value of TDS in comparison to the River Kali because when water from the river enters into the soil matrix, it dissolves many soluble salts present in the soil. But a close relationship is observed between the river water and pumping well water.

Variation of Total Coliform Counts

The total coliforms present in groundwater are below the detectable limit. But River Kali contains a large number of total coliform groups of bacterial colonies. The variation of total coliforms is in the range of 95 to 2400 counts/100 mL of sample. But pumping well water contains total coliforms in the range of 2 to 28 counts/100 mL of sample. It is obvious from Figure 8 that riverbank filtration is proved to be very effective in removing total coliforms to a great extent.

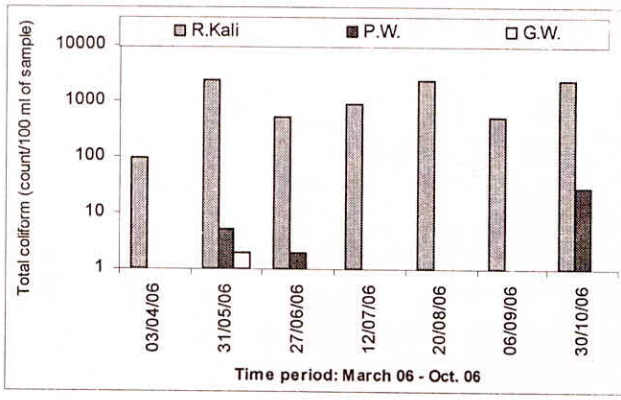

Fig. 8: Total coliform in Kali River water, filtrate and groundwater

Variation of Faecal Coliform Counts

- The faecal coliforms present in groundwater are beyond the detectable limit. The River Kali contains a large number of faecal coliform groups of bacterial colonies and they varied in the range of 23 to 1500 counts/100 mL of sample. In case of pumping well water faecal coliform was observed in the range of 0 to 11 counts/100 mL of sample. Thus, riverbank filtration is very effective in removing the faecal coliform to a great extent, as shown in Figure 9.

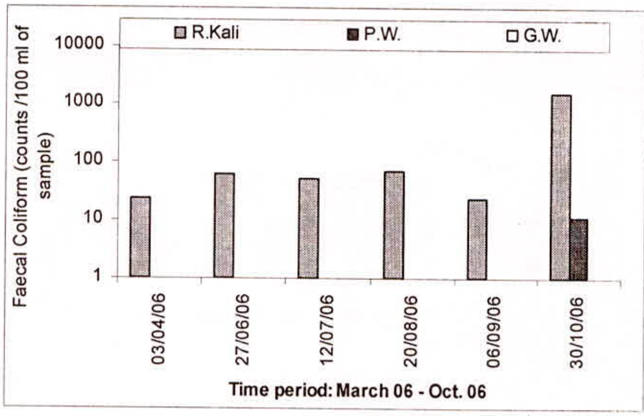

Fig. 9: Faecal coliform in Kali River water, filtrate and groundwater

CONCLUSIONS

Based on study of riverbank filtration in extreme environmental condition the following conclusion can be made:

- There is a distinct reduction in the turbidity.
- The chemical parameters like total dissolved solid and total hardness increase after riverbank filtration.
- A significant removal of total coliform and fecal coliform is observed during riverbank filtration.

ACKNOWLEDGEMENTS

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