Effectiveness of River Bed Filtration in Pollutant Removal Along the River Tel, India

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Abstract Riverbank filtration (RBF) is a cost-effective water treatment technology. In this method, infiltrated surface water is extracted through a pumping well which is located nearby alluvial aquifer. In the process of infiltration surface water is treated by various mechanisms like biological, chemical, and physical processes; hence, water extracted from pumping well is free from pollutants. Although riverbank filtration (RBF) was used extensively in United States and Europe, but there are no proven scientific researches done related to RBF use in Odisha. This paper is aimed to present a concise summary of the theoretical foundations of the RBF technique and its benefits. The paper also reports the effectiveness of bed filtration in reducing turbidity, phosphates, coliform, and nitrates from water of River Tel at Belagaon, Balangir District, in Odisha.

Keywords RBF · Turbidity · Phosphates · Coli form and nitrates

1 Introduction

Riverbank filtration provides a sustainable and cost-effective means which improves the quality of surface water [1]. Mechanisms like physicochemical filtration, biodegradation, and sorption usually occur in the aquifer and the river bed, during river bank filtration process. RBF helps in attenuating the pollutants like micropollutants, parasites, viruses, bacteria, suspended particles, and other organic, and inorganic compounds usually present in surface water [2, 3]. Some researchers studied

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the removal of turbidity, organics, and bacteria at RBF site at Haridwar alongside the Ganga River [4]. RBF technique was reported as an effective method for attenuating pollutants like turbidity and bacteria present in surface water of four rivers of Uttarakhand [5]. River bed material plays a vital role in the treatment of river water during RBF. Potential RBF sites like Badamadhapur and Kuchinda present in Odisha were analyzed, and it was seen that RBF technique was helpful in enhancing the surface water quality parameters making it suitable for drinking purposes [6]. Riverbank filtration has been extensively studied across the world, but very limited research has been done on River bed filtration in Odisha. As the Belgaon site was near to our University and easily accessible, hence in the present study, the effectiveness of River bed filtration in Odisha was evaluated in removing pollutants from surface water.

2 Study Area and Methodology

2.1 Study Area and Hydrology

Out of 29 states in India, Odisha is situated in the eastern part; it extends from 17.31° N latitude to 22.31° N latitude and from 81.31° E longitudes to 87.29° E longitude. The state's six major rivers are Subarnarekha, Budhabalanga, Baitarani, Mahanadi, Brahmani, and Rusikulya. Odisha generally has sub-humid climatic conditions, and precipitation is approximately 1491 mm and gets approximately 75–80% of rainfall during June to September.

3 Site Selection

River Tel with water supply scheme at Belgaon, Balangir District, was selected for the study.

Belgaon is situated at outskirts of Balangir district, Odisha 50 km away from Balangir headquarter. It is situated in the western part of Odisha. Its latitude is 20° 19′ 08.8″ N and longitude is 83° 18′ 57.5″ E, and is located near River Tel. Figure 1a shows sampling locations at river bank filtration site. The production well (Fig. 1b) is situated on the river bank (within 2 m from River Tel) which is getting water through the laterals connected to it. Water from the river is entering into the laterals after passing through the river bed. The depth of production well below bed level is 20 m, and its diameter is 2 m. It originates from the plains in Koraput district. Discharge at the production well was around 0.2 m^3/min. In the present study, the water samples were collected directly from Tel river as well as from production well (river bed filtrated water), and tube wells (groundwater) near the river. Collected

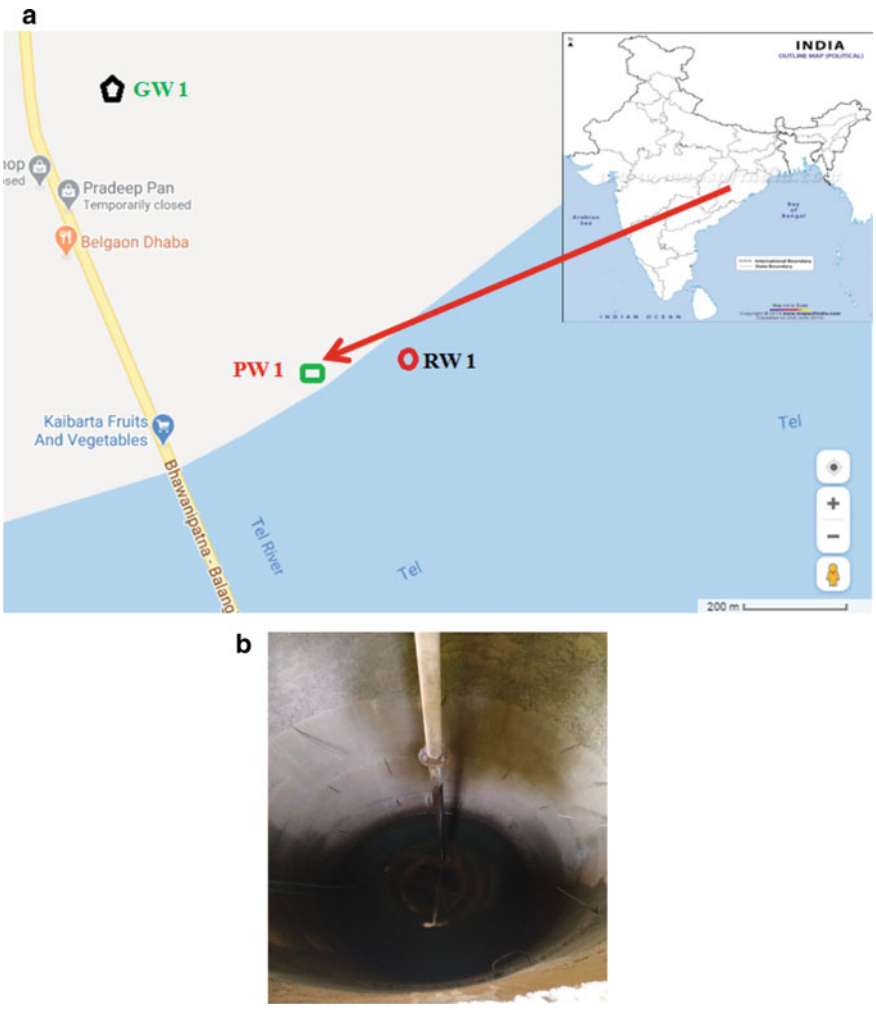

Fig. 1 **a** Sampling locations at river bank filtration site. **b** Inside view of the production well

water samples were tested in the laboratory. In addition, soil samples taken from the river bed at a depth of 1 m were subjected to sieve analysis for gradation of soil.

4 Sieve Analysis of Soil Collected from River Bed

IS code was used for grain size analysis of the soil sample [7]. The soil sample was collected at a depth of 1 m from the river bed. Dry sieve analysis was done at laboratory, and the percentage finer and particle size graph was plotted (Fig. 2).

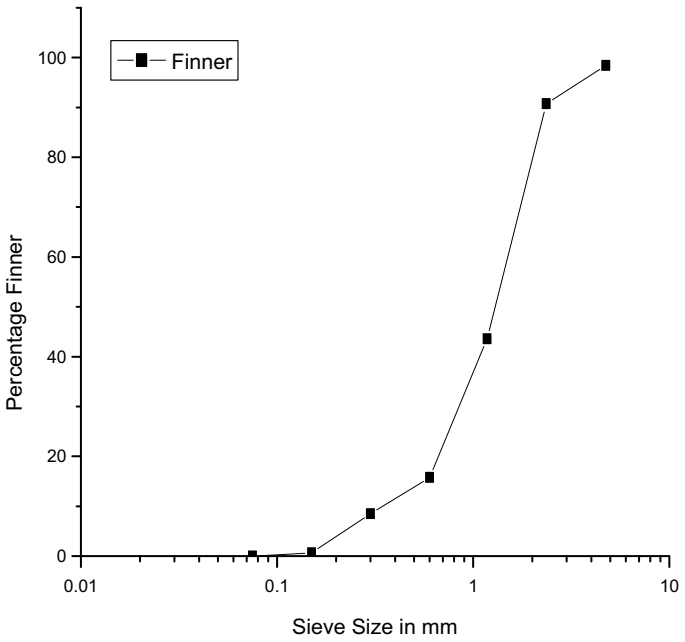

Fig. 2 Particle size distribution curve

5 Methodology

The water samples were collected from surface water, i.e., the Tel river RW1 (Belgaon) as well as from the production well PW1 (river bed filtrated water), tube well GW1 (groundwater) during different seasons/time using clean and sterilized bottle (sampling location are shown in Fig. 1a). All the water sample tests were performed in the laboratory of environmental engineering. The standard methods like [8] were used in the collection of water samples. Various tests like sieve analysis [7], pH (pH meter), total dissolved solids, and temperature (TECH TEST water quality tester TDS meter and temperature), e-conductivity (HM digital conductivity meter), turbidity (turbidity meter), hardness (Wanklyn solution method), alkalinity [9], chlorides [9], fluoride (pH/ISE meter-thermo scientific Orion Star), total coli form (MPN test) and phenol, phosphate, nitrate, UV absorbance (UV spectrophotometer) were done as per respective standards using appropriate instruments.

6 Results and Discussion

The results obtained from the analysis of different water quality parameters and aquifer characterizations are discussed in subsequent paragraphs.

6.1 Water Quality and Soil Analysis

Water samples are collected from different locations of Belgaon and analyzed in the laboratory for different water quality. Here, the river water was raw water (RW), production well water (PW1) was the river bed filtered water, and ground water was the tube well water. Water quality monitoring was done in 15 phases for the year 2018–19, considering time periods like monsoon, post-monsoon, and summer. Each time period comprised of five phases. Water samples were collected from River Tel (RW1; surface water), production well (PW1, riverbank filtered water), and one deep bore well which is at a distance of more than 1 km from the Tel River (GW1, groundwater) at Belgaon. Water sample results from different sources, i.e., river water, production well, and tube well are given in Table 1.

7 Percentage Removal of Pollutants

From Fig. 3, it can be noticed that phosphate removal percentage varied between a lowest (minimum) value of 10.53% to a highest (maximum) value of 35.91%. The average removal percentage was reported as 17.94%. Similarly, it can be noticed that phenol removal percentage varied between a lowest value of 14.15% to a highest value of 28.71%. The average removal percentage was reported as 20.63%. It can be noticed that turbidity removal percentage varied between a lowest value of 99.62% to a highest value of 99.86%. The average removal percentage was reported as 99.76%. It can be noticed that total coliform removal percentage varied between a lowest value of 96.17% to a highest value of 99.73%. The average removal percentage was reported as 98.69%. It can be noticed that nitrate removal percentage varied between a lowest value of 3.15% to a highest value of 6.15%. The average removal percentage was reported as 4.92%. It can be noticed that UV absorbance removal percentage varied between a lowest value of 10.43% to a highest value of 30.36%. The average removal percentage was reported as 16.91%. From Fig. 3, it can be concluded that pollutants like turbidity and total coliform removal percentages were more compared to other pollutants like phosphate, phenol, nitrate, and UV absorbance.

Figure 4 shows the relative values of water quality parameter for the production well water and the river water. The parameters such as TDS, conductivity, alkalinity, chloride, fluoride, and hardness values are greater than 1, i.e., the values of production well water are greater than river water. From Fig. 5, it was found that the parameters such as turbidity, nitrate, total coliform, phenol, phosphate, and UV absorbance values are less than 1, i.e., the values of river water is greater than production well water. Here, we found that the TDS and conductivity of the production well water is more than that of the river water because the production well water is mixture of river water (having lower TDS and conductivity) and ground water (having higher TDS and conductivity). From the above results, we found that bed filtration has effectively removed turbidity, coliform bacteria, organics (UV abs. and total coliform), and

Table 1 Comparison of different parameters of river water, production well water, and tube well water (ground water)

	River water			Production well water			Tube well water		
Parameter	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
pH	9.5	9.8	9.65	7.4	7.4	7.4	6.6	7	6.8
TDS in mg/l	78	78	78	131	135	133	302	352	327
Electrical conductivity in μs/cm	160	165	162.5	288	296	292	674	713	693.5
Temperature in °C	30	32	31	29	29	29	31	32	31.5
Turbidity in NTU	26.5	74	45.48	0.1	0.1	0.1	NA	NA	NA
Hardness in mg/l as $CaCO_3$	46	86	65.73	116	140	127.2	108	108	108
Alkalinity in mg/l as $CaCO_3$	165	190	175	185	215	198.8	170	450	310
Chloride in mg/l	2.58	7.8	4.9	5.24	11.36	8.4	29.82	56.8	43.31
Fluoride in mg/l	0.46	0.64	0.576	0.71	0.78	0.74	1.9	3.1	2.5
Total coli form MPN	16,000	110,000	48,766.67	300	920	380	NA	NA	NA
Phenol in mg/l	0.22	0.26	0.24	0.18	0.20	0.19	NA	NA	NA
Phosphate in mg/l	1.69	2.47	1.98	1.32	1.76	1.61	1.60	2.28	1.94
Nitrate in mg/l	6.58	6.93	6.76	6.25	6.59	6.42	6.15	6.44	6.30
UV Abs (254 nM)	0.784	1.007	0.851	0.693	0.715	0.704	0.7	0.686	0.693

phosphate and reduce hardness. In this process, we remove some amount of phenol, but it remains above the Indian drinking water standards, i.e., 0.001 mg/l. The river bed filtration at Tel River, Belgaon, was found to be efficient for the removal of turbidity, organics (UV abs, phenol), nutrients (phosphate and nitrate), and bacteria (total coliform). Bed filtration is effective in removal of turbidity and total coliform for all the collected samples. This may be due to combination of several processes, including physicochemical filtration, dispersion, advection, and straining. Among above-mentioned processes, physicochemical filtration play a major role in attenuating the pollutants like turbidity and coliform from the river water. The removal of organics at the site may be due to a combination of several mechanisms, including

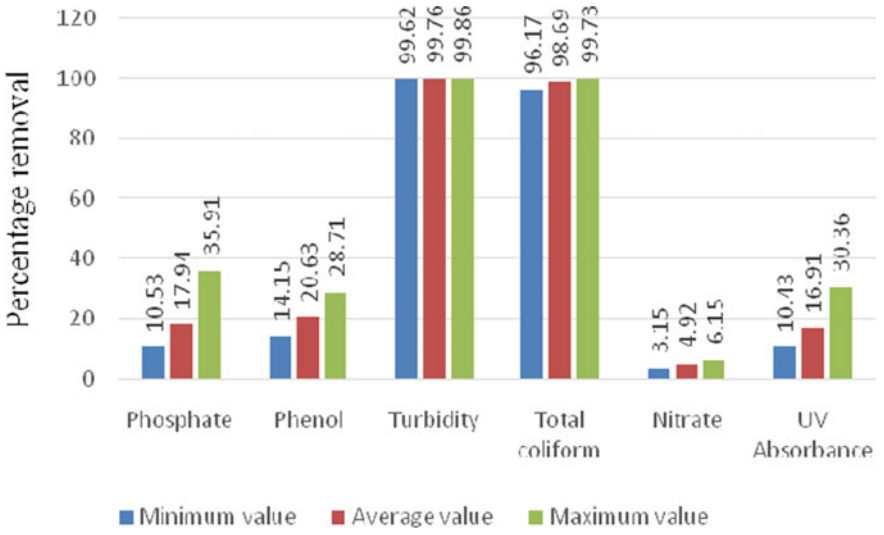

Fig. 3 Maximum, minimum, and average percentage removal of different water quality parameters

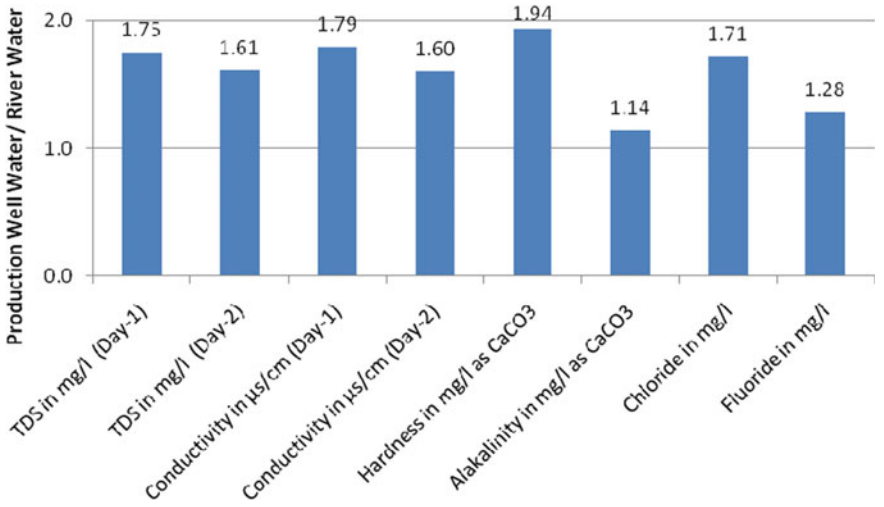

Fig. 4 Quality of production well water relative to river water parameter

dilution with other water; microbiological, chemical, and physical degradation. For other parameters such as TDS, total hardness, anions, and cations of well water is more than that of the river water because the water in the well is mixture of river water (having lower TDS, cations, anions, hardness), and ground water (having higher TDS, cations, anions, and hardness). The aquifer bed at Tel river is found to

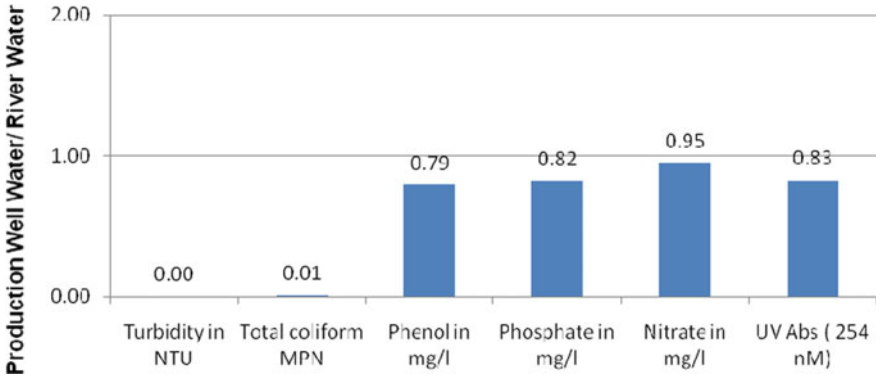

Fig. 5 Turbidity, organics, nutrients, and coliform counts of production well water relative to river water

be sandy and aquifer possesses high hydraulic conductivity which is good in getting sufficient yield (0.2 m^3/min) for the infiltration wells.

8 Conclusions

The study concludes that at the RBF study site in Belgaon, the pH of production well water are within the limit [10], i.e. 6.5–8.5. The electrical conductivity and TDS of the production well water is greater than the river water, whereas it is less than the tube well water. This concludes that the ground water mixing is taking place along with river bed filtration. The RBF in Belgaon (Tel River) efficiently removes turbidity, phosphates, and nitrates. The most probable number (MPN) value of the river water is more than the production well water and the removal efficiency of bacteria is more than 99% during bed filtration. The UV absorbance value of the production well water is less than the river water, which is conclusive of the removal of organic matter. The RBF does reduce the phenol content but not up to the Indian drinking water standard. The results of this work have demonstrated the benefits of bed filtration which is a natural purification technique to enhance the quality of surface water in terms of removal of pathogens, organics, and turbidity for drinking water supply. As natural attenuation process like filtration requires low routine maintenance, hence RBF is a cost-effective alternative for water supply schemes which relies on surface water supplies. RBF method possesses some limitations. These limitations depend on parameters like permeability and high organic pollution. It can be noted that change in temperature can change the permeability of the aquifer and hence the performance of RBF. Similarly, high organic pollution can reduce the RBF treatment efficiency.

References

1. Tufenkji N, Ryan JN, Elimelech M (2002) The promise of bank filtration. Environ Sci Technol 36(21):422A–428A
2. Kuehn W, Mueller U (2000) Riverbank filtration—an overview. J Am Water Works Assoc 92(12):60–69
3. Sacher F, Brauch HJ (2002) Experiences on the fate of organic micro pollutants during riverbank filtration. In: Ray C (ed) Riverbank filtration: understanding contaminant biogeochemistry and pathogen removal. Kluwer, Dordrecht, pp 135–151
4. Dash RR, Prakash EVPB, Kumar P, Mehrotra I, Sandhu C, Grischek T (2010) River bank filtration in Haridwar, India: removal of turbidity, organics and bacteria. Hydrogeol J 18(4):973–983. https://doi.org/10.1007/s10040-010-0574-4
5. Tyagi S, Dobhal R, Kimothi PC, Adlakha L, Singh P, Uniyal DP (2013) Studies of river water quality using river bank filtration in Uttarakhand, India. Water Qual 5. https://doi.org/10.1007/s12403-013-0097-z
6. Sahu RL, Dash RR, Pradhan PK, Das P (2019) Effect of hydrogeological factors on removal of turbidity during river bank filtration: laboratory and field studies. Groundwater Sustain Dev 9:100229. https://doi.org/10.1016/j.gsd.2019.100229
7. IS 2720 (1985) Indian standard on methods of test for soils, part 4. Grain size analysis (second revision). Bureau of Indian Standards, New Delhi, India
8. APHA, AWWA, WPCF Standard methods for the examination of water and wastewater, 19th, 20th and 21st eds. American Public Health Association, Washington, DC (1995, 1998, 2005)
9. IS 3025 (1986, 1988) Methods of sampling and test for water and waste water. Bureau of Indian Standards, New Delhi, India
10. IS 10500 (2012) Indian standard on drinking water: specifications. Bureau of Indian Standards, New Delhi, India