# River Bank Filtration: An overview

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**ABSTRACT**

For more than one hundred years, riverbank filtration (RBF) has been used to produce drinking water by inducing surface water to flow downward through sediment and into a pumping well. During this process, potential contaminants are filtered from the water, significantly improving water quality. This paper explores the mechanics behind RBF, its ability to remove contaminants from surface water, and critical research needs.. Its purpose is to show that RBF is a low-cost and efficient alternative water treatment process for drinking-water applications. The need for the use of RBF in India is also emphasized.

**Key words:** River Bank Filtration, River Bank filtrate, Contaminant Removal.

## INTRODUCTION

The quality of drinking water has always been a major concern. Rivers are the most important sources of drinking water. In arid regions, most rivers lose flow and the percolating water passes through soil and aquifer material until it reaches the water table. During these percolation processes, potential contaminants present in river water are filtered and attenuated. In River Bank Filtration (RBF), water from the river passes through the porous media (aquifer) due to the pressure ‘head’ difference between the river and aquifer before it is drawn up through wells. RBF has been in use for more than 100 years. However the pumped water also called riverbank filtrate is a mixture of ground water originally present in the aquifer and the infiltrated surface water from the river. At a minimum, RBF acts as a pretreatment step in drinking water production and in some instances, can serve as the final treatment just before disinfection.

**River Bank filtration Systems:**

For more than 100 years, RBF has been used in Europe, most notably along the Rhine, Elbe, and Danube Rivers, to produce drinking water. Although RBF is not commonly utilized in the United States, interest is increasing in using RBF as a low cost complement or alternative to filtration systems to remove pathogens from water.

Most RBF systems are constructed in alluvial aquifers located along the river banks. These aquifers can consist of a variety of deposits ranging from sand, to sand and gravel, to large cobbles and boulders. Ideal conditions typically include coarse grained, permeable water bearing deposits that are hydraulically connected with river bed materials. Historically, three types of wells have been used for RBF since the technology was first established in the 1800s. They include:

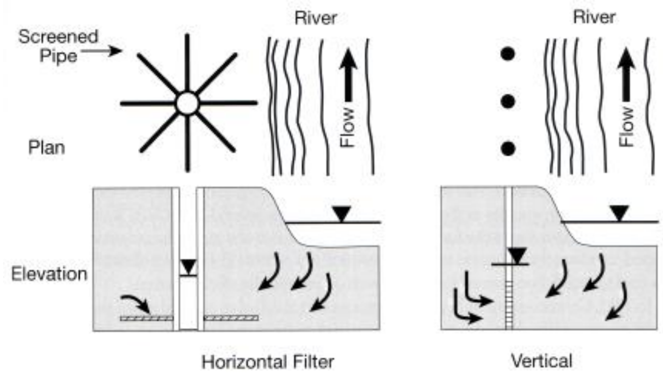
*Horizontal collector wells:* A circular central collection caisson sunk into the ground with horizontal lateral well screens pushed out into unconsolidated aquifer deposits, in many cases into alluvial deposits beneath a river or lake. These are typically used in United States (called collector wells)

*Vertical Wells:* A tubular well that is drilled vertically downward into a water bearing stratum or under the bed of a lake or stream.

*Pit Wells:* These are shallow large diameter wells that, in many cases are manually dug into the ground.

Another historical well used for RBF was a *perforated collector pipe* located in a shallow aquifer, which functioned as an infiltration gallery.

Drilling and construction technologies were developed at the end of $19^{th}$ century that allowed pit wells to be replaced with vertical filter wells. After the development of siphon tube concept, this was used to extract water from a great number of vertical filter wells at one time using only one pump. Siphon systems are generally connected via a discharge manifold to one or more suction pumps. They are used in shallow aquifers where water level is lower than the suction lift of pumps. The advantages of this technique are – Low Operation and Maintenance costs; Easy adaptation to varying raw water demand; and Uniform stress of production wells during operation.




Traditionally, vertical wells are used for developing ground water supplies in alluvial aquifer systems. The screen lengths of vertical wells are controlled by the saturated thickness of aquifer and pump setting. During the last 70 years, horizontal collector wells have been developed for the production of ground water in unconsolidated, water filled sediments. Some distinct advantages of horizontal collector wells are – More of the available drawdown can be used (since well screens can be installed at a lower elevation in the aquifer) ; More well screen can be exposed to the aquifer at a given site since screen length is not limited by saturated thickness of the formation. There is a continuous debate over the selection of type of well. The decision in each particular case must regard site conditions, most notably the hydro geological situation of the aquifer and the hydraulic conditions in the river, especially concerning river bed clogging. The saturated thickness of the aquifer should not be less than 6m and the transmissivity in the range of 1500 $m^2$/day or higher. If the site conditions do not restrict the use of collector well, the capital, operation and maintenance costs of both alternatives should be compared for life cycle costs.

**Water Contaminants and their removal in RBF:**

For an RBF system, to operate effectively, it must remove contaminants in raw surface water from rivers, lakes and reservoirs. Utilities must ensure that RBF systems are properly designed and operated to maximize contaminant removal. The fact that these contaminants may fluctuate seasonally must also be considered.

*Physical Contaminants:*

Temperature and Turbidity are the physical contaminants of greatest concern. In temperate climates, depending upon season surface water temperature would range from freezing to ±35°C. But ground water temperature remains relatively unchanged (±15°C). The variation of temperature can be a function of pumpage, monitoring point location, distance of river to the well, well construction and other hydro-geologic factors. Ground water provides the best moderation of temperate fluctuation. River bank filtrate also provides significant moderations.

Turbidity is a concern for rivers that traverse through clay rich formations.

*Chemical Contaminants:*

Chemical contaminants can be divided into four major groups:

- Inorganics
- Synthetic Organics (Pesticides and Volatile/Semi Volatile organics)
- Natural organic content (NOM)
- Pharmaceuticals and other emerging chemicals.

Regarding Inorganics, the hardness of river water is of concern to water utilities where hardness removal is a major treatment unit operation. Hardness can be reduced during peak flow periods when the contribution from groundwater is low. Nitrogen and other forms of fertilizers are also of concern.

Synthetic organic chemicals and pesticides are of great concern in surface-water treatment. Rivers that traverse through agricultural watersheds receive large loads of pesticides in spring runoff, similar to that of nitrate. Moreover, navigable rivers are also subject to accidental releases of petroleum products and other industrial chemicals, such as chlorinated compounds. These all contribute to shock loads (river water with a temporary and unusual amount of pollutants). In addition to shock loads, rivers can carry residual chemicals for a significant amount of time.

NOM in surface water is a major concern for water utilities that use chlorine as the disinfectant. Chlorine combines with NOM to form disinfection byproducts, such as trihalomethanes (THMs) and haloacetic acids (HAAs), which are potentially carcinogenic. NOM concentrations and speciation vary depending upon the season, watershed characteristics, and river flow. The following water-quality parameters that are typically used as indicators of NOM in source water include, but ate not limited to:

• Total organic carbon (TOC).

• Dissolved organic carbon (DOC).

• Biodegradable organic carbon.

• Ultraviolet absorbance of water at 254 nanometers (nm).

• Assimilative organic carbon.

Pharmaceuticals and personal care products are micro pollutants (detected at microgram-per-liter, nanogram-per-liter) ranges of recent concern to drinking-water utilities. Many pharmaceuticals and personal care products are found in domestic sewage, and some pharmaceuticals and personal ire products are endocrine disrupting chemicals. Only a small subset of pharmaceuticals and personal care products is suspected to be direct-acting endocrine disrupting chemicals. Major chemicals from pharmaceuticals and personal care products found in most of the rivers include clofibric acid, diclofenac, ibuprofen, phenazone, primidone etc. Other chemicals of interest include:

• Absorbable organic halogen.

• Absorbable organic sulfur.

• Nitrilotriacetic acid (NTA).

• Ethylene diamine tetra acetic acid (EDTA).

• Diethylene trinitrolo penta acetic acid (DTPA).

• Aromatic sulfonates.

NTA, EDTA, and DTPA are widely used as chelating agents in detergents and industrial cleaners and in the textile, photo, and pulp and paper industry.

The processes involved in the removal of chemical contaminants include sorption and desorption, filtration and colloids, biotic and abiotic degradation and volatilization.

Sorption depends on the structure and position of functional groups of the sorbate; presence and degree of molecular unsaturation of the sorbent; chemical characteristics of the sorbate such as acidity, water solubility, mineralogical compositions; organic matter content; cation exchange capacity and microbial activity of the sorbent. Many organic pollutants are hydrophobic which indicates that these substances have a lower affinity for solutions in water and prefer solutions in apolar liquids. These pollutants are readily adsorbed by the organic matter or sediments. Except for herbicides, most pesticides tend to be hydrophobic rather than lipophobic.

Colloids which are particles varying in size from 1 to 1000 nm include microorganism, large macromolecules, and inorganic fragments. The migration of particles provides a way for mass transport in the subsurface either as contaminants or as contaminants sorbed onto these particles. Electrostatic forces result in colloidal transport velocity that exceeds ground water flow velocity. On the other hand, physical and chemical processes may lead to a filtration of colloids.

Organic substances can be transformed into simpler inorganic forms by biotic and abiotic degradation. The important abiotic transformation reaction for many organic substances is hydrolysis. The degradation of organic compounds is often related to redox processes especially oxidation reactions. These reactions are referred to as biodegradation because they are microbiologically catalyzed. *Volatilization* amounts to a loss of pesticides on the order of 5 to 10 percent of total mass in surface water. It is controlled by physical and chemical characteristics of the compound, its concentration, soil water content, air movement, air temperature and diffusion processes.

Results from the experiments reveal the following –

- Biodegradation is the primary mechanism for removing NOM and other contaminants. For instance, NOM removal occurs within the first 15 meters of infiltration.
- RBF can remove more than 50% of NOM and disinfection byproduct precursors from surface water.
- RBF can remove between 35 to 67 % of TOC and DOC from surface water, which also significantly reduces disinfection byproduct potentials by 53 to 82 % (THM) and 47 to 80 % (HAA).
- RBF has greater reductions in theoretical cancer risk (28 to 45 % reduction) due to removing THM than conventionally treated water (11 to 47 %).
- Some micro pollutants showed only partial or no significant removal during RBF, including aromatic sulphonic acids, EDTA, naphthalene – 1, 5 – disulphonate, chlofibric acid, carbamazepine, or x ray contrast agents and hence require additional post treatment.

*Biological Contaminants*

Biological contaminants in surface water include protozoa, bacteria, and viruses. *Cryptosporidium* and *Giardia* are the two major waterborne protozoa of concern. Fecal and total coliform bacteria and, in some cases, the spores of aerobic and anaerobic bacteria are also monitored. In addition, human enteric viruses and bacteriophage are monitored at some European and American RBF sites.

During soil passage, microbes may be removed from the aqueous phase primarily by straining, inactivation, and attachment to the aquifer grains. Other removal processes of uncertain significance are – sedimentation in connected pores and trapping in the dead end pores.

*Inactivation*

Viruses loose their ability to infect the host cells with time by inactivation. This occurs due to the disruption of coat proteins and the degradation of nucleic acids. This is usually regarded as a first order process. The important factors influencing virus inactivation rates during saturates subsurface transport are temperature, adsorption to particular matter and soil microbial activity.

Bacteria have their own optimum growth temperatures – Psychrophyllic bacteria have maximum growth below 20ºC; Mesophilic bacteria between 20 to 30ºC; Thermophilic bacteria above 40ºC. A decrease in temperature usually prolongs the persistency of microorganisms in soil and aquifer materials.

*Straining*

Straining is a purely physical removal process governed by the size of the pore throats and microbial particles. It depends mainly on the ratio of diameter of the media to the diameter of the particle. If the ratio is greater than 20, straining is insignificant; between 10 to 20, it is significant; and below 10, no particle penetration through porous media occurs. Because of smaller size, the straining of bacteria is less important than for protozoa and negligible in case of bacterial spores. Straining of viruses does not occur where clogging is insignificant.

Sedimentation and colloidal filtration also reduce the microbial content. In colloidal filtration, a suspended particle may come into contact with a particle of the solid medium, the collector, either by interception, sedimentation or diffusion.

Results from the experiments indicate RBF can achieve upto 8 log virus removal over a distance of 30 meters in about 25 days under optimal conditions. Greater removal efficiency may be expected for bacteria, protozoa, and algae under the similar conditions RBF can reduce biological regrowth potential by more than 60 percent. RBF significantly reduces mutagenic activity. The number of induced revertants in well water (20/L) was much lower than in river water (about 250/L).

**River Bank filtration in India**

River Bank Filtration is not an entirely new concept in India. There are evidences of abstraction of water from the wells located near river banks. Very old dugwells can still be seen in Varanasi, Kanpur, Allahabad, Patna, Delhi and Calcutta. The immense potential of RBF in India can be accounted to its long riverine stretch of about 45000 Km. Furthermore, since both the river banks may be used for RBF, the total available riverine stretch is about 90000km. However a part of this length (around 33%) is unsuitable for RBF due to pollution from the neighbouring towns and cities. The pollution has increased to such an extent that there is no self regeneration in many rivers. We have failed to apply these ancient techniques appropriately by choosing the hastier and easier alternatives such as tubewells.

Abstraction of water from the infiltration wells contributes a significant quantity to the potable water supply for a few towns and cities. For example, 38% of the water supply is derived from the infiltration wells at Hardwar and 62% of water supply of Muni ki Reti near Rishikesh is met through Infiltration well situated on the bank of river Ganga. Around 90% of water for Nainital town water supply is abstracted through shallow wells near Nainital Lake.

Studies have been conducted at RBF sites established across the Ganga River at Hardwar, Patna and Varanasi. The results are tabulated as shown below

| | Cond µS/cm | Ca mg/L | Mg mg/L | Na mg/L | K mg/L | Cl mg/L | SO4 mg/L | NO3 mg/L | SiO2 mg/L | PO4 mg/L | TOC mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Well no. 18 | 510 | 66 | 18.3 | 11 | 5.1 | 21 | 28 | 7.6 | 12 | < 0,1 | 1.4 |
| Well no. 24 | 263 | 34 | 9.0 | 6 | 3.8 | 5 | 20 | 8.2 | 9 | < 0,1 | 0.30 |
| Well no. 26 | 726 | 94 | 26.0 | 19 | 5.8 | 16 | 24 | 11.9 | 19 | < 0,1 | 0.94 |
| Well no. 40 | 652 | 88 | 19.4 | 21 | 4.7 | 20 | 26 | 11.9 | 15 | < 0,1 | 1.5 |
| Well no. 49 | 279 | 39 | 9.5 | 4 | 3.2 | 2 | 21 | 2.1 | 9 | < 0,1 | 1.5 |
| River Ganga | 252 | 30 | 9.9 | 4 | 2.1 | <2 | 26 | 1.6 | 9 | < 0,1 | 0.55 |
| Ganga Canal | 249 | 30 | 9.9 | 4 | 2.0 | <2 | 25 | 1.5 | 9 | < 0,1 | 0.71 |
| MW 1 | 385 | 49 | 14.1 | 7 | 4.2 | 6 | 20 | 2.9 | 11 | < 0,1 | 1.5 |
| MW 2 | 395 | 52 | 15.2 | 6 | 4.4 | 4 | 19 | 0.6 | 11 | < 0,1 | 1.2 |
| Tap water | 276 | 37 | 9.0 | 4 | 3.0 | <2 | 23 | 1.9 | 9 | < 0,1 | 0.61 |

| | Fe mg/L | Mn mg/L | As mg/L | Ba mg/L | Cu mg/L | Ni mg/L | Pb mg/L | Cr mg/L | Cd mg/L | Tl mg/L | Zn mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Well no. 18 | < 0.01 | 0.11 | 0.005 | 0.17 | < 0.01 | < 0.002 | < 0.002 | < 0.002 | < 0.0005 | < 0.002 | 0.04 |
| Well no. 24 | < 0.01 | 0.08 | 0.007 | 0.07 | < 0.01 | < 0.002 | < 0.002 | < 0.002 | < 0.0005 | < 0.002 | < 0.015 |
| Well no. 26 | < 0.01 | 0.11 | 0.009 | 0.26 | < 0.01 | < 0.002 | < 0.002 | < 0.002 | < 0.0005 | < 0.002 | 0.02 |
| Well no. 40 | < 0.01 | < 0.02 | 0.004 | 0.15 | < 0.01 | < 0.002 | < 0.002 | < 0.002 | < 0.0005 | < 0.002 | < 0.015 |
| Well no. 49 | < 0.01 | < 0.02 | 0.005 | 0.07 | < 0.01 | < 0.002 | < 0.002 | < 0.002 | < 0.0005 | < 0.002 | < 0.015 |
| River Ganga | < 0.01 | < 0.02 | 0.006 | 0.03 | < 0.01 | < 0.002 | < 0.002 | < 0.002 | < 0.0005 | < 0.002 | < 0.015 |
| Ganga Canal | < 0.01 | < 0.02 | 0.006 | 0.03 | < 0.01 | < 0.002 | < 0.002 | < 0.002 | < 0.0005 | < 0.002 | < 0.015 |
| MW 1 | < 0.01 | < 0.02 | 0.003 | 0.12 | < 0.01 | < 0.002 | < 0.002 | < 0.002 | < 0.0005 | < 0.002 | 0.02 |
| MW 2 | < 0.01 | < 0.02 | 0.005 | 0.12 | < 0.01 | < 0.002 | < 0.002 | < 0.002 | < 0.0005 | < 0.002 | < 0.015 |
| Tap water | < 0.01 | < 0.02 | 0.006 | 0.07 | < 0.01 | < 0.002 | < 0.002 | < 0.002 | < 0.0005 | < 0.002 | 0.18 |

*Source: Report of Ronny Sachse Oct. 05 – Dec. 05*

| S.NO | PARAMETERS | IW-17 | IW-24 | IW-25 | IW-29 | IW-42 | IW-43 | IW-44 | CA-17,44 | CA-29 | CA-24, 25, 42, 43 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Turbidity (NTU) | 0.50 | 0.60 | 0.70 | 0.50 | 0.60 | 0.50 | 0.50 | 2.00 | 2.50 | 1.50 |
| 2 | Total dissolved solids (mg/L) | 199 | 199 | 230 | 193 | 220 | 198 | 152 | 141 | 225 | 196 |
| 3 | TOTAL COLIFORM(MPN/100mL.) | N.D. | 9 | N.D. | 4 | N.D | N.D | N.D | 110 | 130 | 100 |
| 4 | FECAL COLIFORM(MPN/100mL.) | N.D. | 3 | N.D. | 2 | N.D | N.D | N.D | 30 | 40 | 20 |

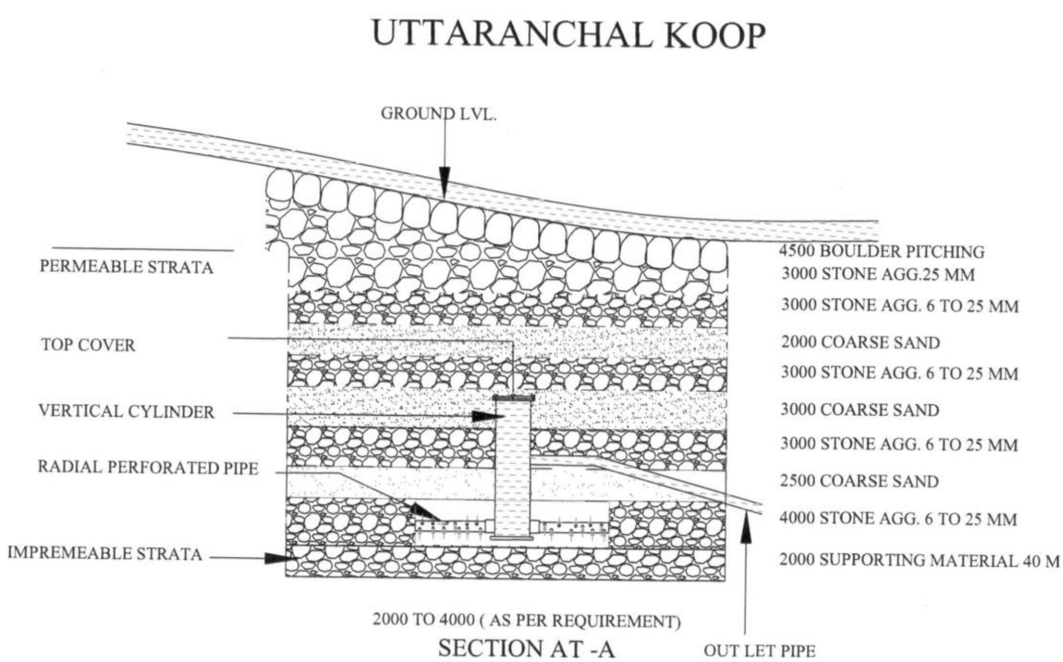
*IW – Infiltration well, CA- Canal* *Source: Report of IITR Sep., 2006*

The turbidity of river water highly depends on river flow conditions. Since the river flow varies seasonally, there is a periodic behavior in the turbidity levels in the river and the river bank filtrate (having a time lag of travel time). Although canal water turbidity fluctuated significantly during the monitoring period, the turbidity in the infiltrate remained stable between 0.5 to 0.7 ntu against 1.5 to 2.5 ntu in the canals.

Although the results at some of the sites could not be obtained, the infiltration wells showed a removal for total coliform ranged from 1 to 1.5 logs with an average of 1.24 logs. Also there is insignificant decrease in the total dissolved solids from the canals and the wells. The results indicate that RBF is an efficient method to remove microorganisms and coliform from source water.

***Sub surface flow***

In hilly area rivers and streams are turbulent and there is not much flat river stretch and the depth of alluvial fill is also very thin. The Uttaranchal Jal Sansthan developed the 'Uttaranchal Koop' which is specially designed to tap the sub surface flow through small rivers and streams, on the basis of River Bank Filtration. Connected with a welded outlet socket at the middle of the vertical cylinder for jointing outlet pipe, the 1 to 1.5 meter long pipe is placed vertically 3 to 4 meter below the bed of the stream with open end at the bottom and closed end at the top. It is placed over impermeable strata of the streams tapping entire alluvial fill. After placing the Uttaranchal Koop, the dug up space is filled up with graded filter media enveloping the Koop up to the natural bed level of stream. The base flow of the stream rises inside the cylindrical pipe through its open end and perforated radial pipes due to the hydrostatic pressure of the submerged surface and maintains a static level in the cylindrical pipe.



*Water Sample Analysis Reports of Uttaranchal Koop (IIT Roorkee)*

| Physical, Chemical & Bacteriological | Permissible limit | Bharatwala (Dehradun) | | Manki (Dehradun) | | Ghorpani (Tehri) | | Kinwani Khala (Tehri) | | Silatala (Pauri) | | Rigaddi (Pauri) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Stream | Koop | Stream | Koop | Stream | Koop | Stream | Koop | Stream | Koop | Stream | Koop |
| | | | | | | | | | | | | | |
| **Turbidity (NTU)** | **10** | **3.24** | **0.733** | **1.34** | **0.38** | **1.41** | **0.34** | **2.76** | **0.86** | **0.96** | **0.56** | **2.18** | **0.98** |
| Specific conductivity (μs/cm) | NS | 570 | **650** | 100 | **110** | 490 | **484** | 307 | **305** | 125 | **125** | 295 | **320** |
| Dissolved solids (mg/L) | 2000 | 382 | **423** | 69 | **72** | 292 | **287** | 194 | **196** | 82 | **78** | 187 | **184** |
| pH | NR | 8.3 | **8.04** | 6.74 | **7.1** | 8.28 | **8** | 8.36 | **7.66** | 7.43 | **7.03** | 8.7 | **8.42** |
| DO (mg/L) | NS | 8.3 | **8** | 7 | **7.3** | 8.5 | **6.7** | 8.8 | **6.4** | 7.8 | **7.8** | 7.3 | * |
| BOD (mg/L) | NS | 3 | **2** | 8 | **2** | LDL | **LDL** | LDL | **LDL** | 14.2 | **16.2** | 20.2 | **18.2** |
| COD (total) (mg/L) | NS | 5.9 | **5.5** | 31.2 | **8.7** | 2 | **LDL** | LDL | **LDL** | 31.8 | **44.3** | 40.5 | **37.1** |
| Total Hardness(mg/L as CaCO3) | 600 | 310 | **348** | 54 | **48** | 236 | **250** | 138 | **144** | 46 | **46** | 138 | **148** |
| Ca+2 (mg/L as CaCO3) | 200 | 122 | **168** | 36 | **34** | 156 | **140** | 92 | **116** | 34 | **30** | 106 | **110** |
| Mg+2(mg/L as CaCO3) | 100 | 188 | **180** | 18 | **14** | 80 | **110** | 46 | **28** | 12 | **16** | 32 | **38** |
| Na+ (mg/L) | NS | 1.2 | **1.8** | 5.4 | **7.2** | 1.4 | **1.3** | 5.1 | **4.9** | 9 | **9.2** | 9.7 | **11.3** |
| K+ (mg/L) | NS | 0.3 | **0.3** | 0.4 | **0.4** | 6.6 | **1.4** | 1.4 | **1.5** | 1.5 | **1.5** | 2.2 | **1.9** |
| HCO3-(mg/L as CaCO3) | 600 | 145 | **182.5** | 47.5 | **30** | 240 | **240** | 130 | **135** | 41 | **39** | 135 | **149** |
| SO4-2 (mg/L) | 400 | 147 | **164** | 8.7 | **9.4** | 16.65 | **17.35** | 20.11 | **19.45** | 7.27 | **7.20** | 17.42 | **20.04** |
| Cl- (mg/L) | 1000 | 0.5 | **1** | 4 | **11** | 3.5 | **4** | 6 | **6** | 5.5 | **7** | 6 | **3.5** |
| **TOTAL COLIFORM (MPN/100mL.)** | - | **2200** | **100** | **2500** | **90** | **19500** | **1950** | **35000** | **1100** | **46000** | **19** | **7800** | **780** |
| **FAECAL COLIFORM (MPN/100mL.)** | - | **90** | **50** | **360** | **14** | **1100** | **59** | **11000** | **122** | **3500** | **5.5** | **4600** | **780** |

*NS: Not Specified, LDL: Least detectable limit.*

The turbidity levels in the koop varied between 0.34 to 0.98 ntu against 0.96 to 3.24 ntu. The hardness of water (measured in terms of mg/L of $CaCO_3$) in the koop is greater than the stream water. It can be observed that there is slight increase in cation and anion concentrations in the 'koop' water. The total coliform removal ranged from 1.0 to 3.38 logs with an average of 1.52 log removal. The results indicate that faecal coliform removal varied between 0.26 to 1.96 logs with an average of 1.13 log removal. Further, the study suggests that the the pH values of water obtained from the 'koop' improved (was closer to 7) than the stream water (which ranged between 6.74 to 8.7)

## Research needs

Though RBF is an effective in improving the water quality, the efficiency of the process depends upon certain factors such as – the hydraulic gradient between the river stage elevation and the ground water elevation. A significant increase in the head on a filter can force particulate material to penetrate or 'break through' the bed and leach into the filter effluent. Therefore, floods adversely affect the water quality in RBF sites. Nevertheless, they aid in reorientation of the soil in the river/aquifer interface and hence, clogging is reduced.

The rate of infiltration depends on the aquifer characteristics (permeability, porosity and thickness), configuration of the well (depth, screen length, pumping length, and period) and location of source of recharge. Recharge may come from precipitation, nearby surface water body or a combination of both. Surface water will flow into an aquifer along a river reach where zone of contribution has lowered the ground water level below the stream stage through a phenomenon called induced filtration.

The design of wells for RBF plants must regard site conditions, most notably the hydro-geological situation of the aquifer and the hydraulic conditions in the river, especially considering the river bed clogging. Over pumping results in higher infiltration velocities at the river/aquifer interface as well as amplified clogging of the interstitial space beneath the river bed, making it inaccessible for rehabilitation and restoration.

Clogging can significantly affect the RBF well yield. It may induce water transport instabilities and lead to preferential flow path ways, similar to those found in unsaturated soils and responsible for the uncharacteristically fast transport of colloids and pathogens. In the absence of preferential transport the thin biologically active zone at the river/aquifer interface may be responsible for much of the filtration attenuation of biocolloids, heavy metals present in river water.

The maintenance of existing RBF schemes such as the control of pumping, monitoring and treatment optimization, along with the design of new schemes with appropriate borehole location and treatment design according to the site assessment, is also an issue of concern. The managing of the schemes calls for the improvement of river water quality by (political) activities by accounting the change in land use of the catchment, optimization of well operation and technical measures undertaken for the river bed. Moreover, additional research must be carried out for the prognosis of effects of changing conditions such as pumping, surface water quality using models.

**Conclusions**

The results of turbidity, total coliform and other dissolved ions show that the RBF process is an effective water treatment process. Moreover it may be observed that the removal efficiency increases with filtration depth with most occurring in the first meter of infiltration.

Based on the above discussions, it is clear that RBF systems can help utilities in various ways.RBF being an asset to these utilities, provides services: drinking water. High quality drinking water provides many unrecognized values which include reduced medical costs, longer life span, and enhanced environments such as wetlands, lakes or rivers where recreational activities are centered. The important values derived from RBF can be tabulated as shown.

| Services and Benefits | Values |
|---|---|
| Contaminant (pathogen/chemical) removal | Reduced medical costs<br>Longer life span<br>Improved productivity<br>Cancer Risk reduction<br>Enhanced environment |
| Reduced Maintenance | Capital cost reduction |
| Improved Reliability (as source water) | Drought protection |
| Nutrient (organic) removal | Reduced Treatment costs<br>Lower regulatory scrutiny<br>Lower monitoring costs |
| Enhanced community supply (due to total dissolved solids reduction) | Greater customer satisfaction<br>Lower corrosion of household plumbing |

As can be seen ,there are numerous advantages in using RBF as a pretreatment technology.The value of RBF is not just found in reduced treatment and delivery costs,but also in the many invaluable services to the consumer,environment and future generations.

India the second most populous country of the world needs to protect and use judicially their natural resources specially water. RBF can be used along the 90,000 Km river course of India.

**References**

Ray C, Melin G, Linsky RB (Ed.), “Riverbank filtration – improving source-water quality”, *Dordrecht, Boston,London, Kluwer Academic Publishers (2002)*

Hunt,H., J.Schubert, C.Ray, (1999) *“Conceptual Design of River Bank Filtration Systems”* presented in International Riverbank Filtration Conference in Nov 1999.

J.Schijven, P.Berger, I.Miettinen (1999) *“Removal of Pathogens, Surrogates, Indicators, and Toxins using River Bank Filtration”* presented in International Riverbank Filtration Conference in Nov 1999.

I.M.Verstraeten, T.Heberer, T.Scheytt (1999) *“Occurrence, Characteristics, Transport and Fate of Pesticides, Pharmaceuticals, Industrial Products, and Personal Care Products at River Bank Filtration Sites”* presented in International Riverbank Filtration Conference in Nov 1999.

W.D.Gollnitz, (1999) *“Infiltration Rate variability and Research Needs”* presented in International Riverbank Filtration Conference in Nov 1999.

P.Baveye, P.Berger, J.Scheijven, (1999) *“Research Needs to improve the understanding of River Bank Filtration for pathogenic microorganism removal”* presented in International Riverbank Filtration Conference in Nov 1999.

Er. H. P. Uniyal (2006) “*River Bank Filtration in India – Existing Efforts and Future Prospects*” presented in EU-India International Riverbank Filtration Conference, Roorkee ,November 2006.

T. Grischek , W. Nestler, (2006) “*Riverbank filtration in Europe*” presented in EU-India International Riverbank Filtration Conference, Roorkee ,November 2006.