Saph Pani

Enhancement of natural water systems and treatment methods for safe and sustainable water supply in India

Project supported by the European Commission within the Seventh Framework Programme Grant agreement No. 282911

Deliverable D 4.4

Recommended Post-treatment Options for Water Utilities Employing Natural Treatment Systems

Work package	WP4 Post-treatment of water from natural treatment systems for different applications
Deliverable number	D 4.4
Deliverable title	Recommended Post-treatment Options for Water Utilities Employing Natural Treatment Systems
Due date	Month 30
Actual submission date	06.07.2014
Start date of project	01.10.2011
Participants (Partner short names)	ANNA, FHNW, HTWD, IITB, IITR, KWB, NGRI, UJS, UNESCO-IHE, VEOLIA, BRGM
Authors in alphabetic order	A. Gupta, C. Sandhu, G. Grützmacher, I. Mehrotra, J. Prock, L. Elango, L. Stamm, M. Groeschke, N. C. Ghosh, P.C. Kimothi, P. Kumar, P. Renganayaki S.K. Sharma, T. Grischek, T. Wintgens and L. Yu
Contact for queries	Saroj Sharma UNESCO-IHE 2601 DA Delft, The Netherlands Phone: +31 15 2151772 Email: s.sharma@unesco-ihe.org
Dissemination level: (**PU**blic, Restricted to other **P**rogrammes **P**articipants, **RE**stricted to a group specified by the consortium, **CO**nfidential- only for members of the consortium)	PU
Deliverable Status:	Final (7 July 2014)

Table of Contents

List of Tables

List of Figures

List of Abbreviations

ARR	Artificial Recharge and Recovery
BF	Bank Filtration
CFU	Colony Forming Units
CW	Constructed Wetlands
DJB	Delhi Jal Board
DOC	Dissolved Organic Carbon
DBP	Disinfection Byproduct
FC	Faecal Coliform
GAC	Granular Activated Carbon
HLR	Hydraulic Loading Rate
IW	Infiltration Well
MAR	Managed Aquifer Recharge
MLD	Million Liters per Day
MPN	Most Probable Number
NTS	Natural Treatment System
OMP	Organic Micropollutants
O&M	Operation and Maintenance
RSF	Rapid Sand Filter
RCW	Radial Collector Wells
RO	Reverse Osmosis
RWH	Rainwater Harvesting
SS	Suspended Solids
SSF	Slow Sand Filter
TC	Total Coliform
TDS	Total Dissolved Solids
TW	Tube Well

1 Introduction

1.1 Background and scope of the report

Work package 4 of EU Saph Pani Project deals with the post-treatment aspects of natural treatment systems (namely bank filtration BF, managed aquifer recharge MAR, constructed wetlands CWs and other natural systems for wastewater treatment). One of the objectives under this work package is to analyze the existing post-treatment systems at the case study sites and recommend options for improvement of the post treatment to the water utilities employing natural treatment systems (NTSs).

Based on the findings of field data collection, water sampling and analysis as well as laboratory-based studies, this deliverable summarizes the water quality concerns at four bank filtration case study sites and outlines recommendations for further improvement of post-treatment systems to ensure safe and sustainable provision of water supply. Additionally, the report also presents the results of the field data collection and analysis of groundwater quality around Periapalayam check dam site (Chennai) and makes recommendations for post-treatment of water abstracted from groundwater wells in the surroundings.

2. Recommendations for BF Case Study Sites of UJS

2.1 Case study site Haridwar

2.1.1 Overview of RBF system and existing post-treatment

The BF system in Haridwar consists of 22 bottom-entry caisson wells (~ 10 m diameter and 7 - 10 m deep) along Ganga River and Upper Ganga Canal, which accounts for nearly 68% (> 43,000 m^3/day) of the total drinking water production for the city of Haridwar (Sandhu and Grischek, 2012). Additionally, groundwater is abstracted using 56 tube wells (vertical wells) from the deeper confined aquifer to meet the water demand of the city. Normally, 12 – 13 wells are operated continuously (24 hours) with the remaining wells operating 9 – 19 hours per day.

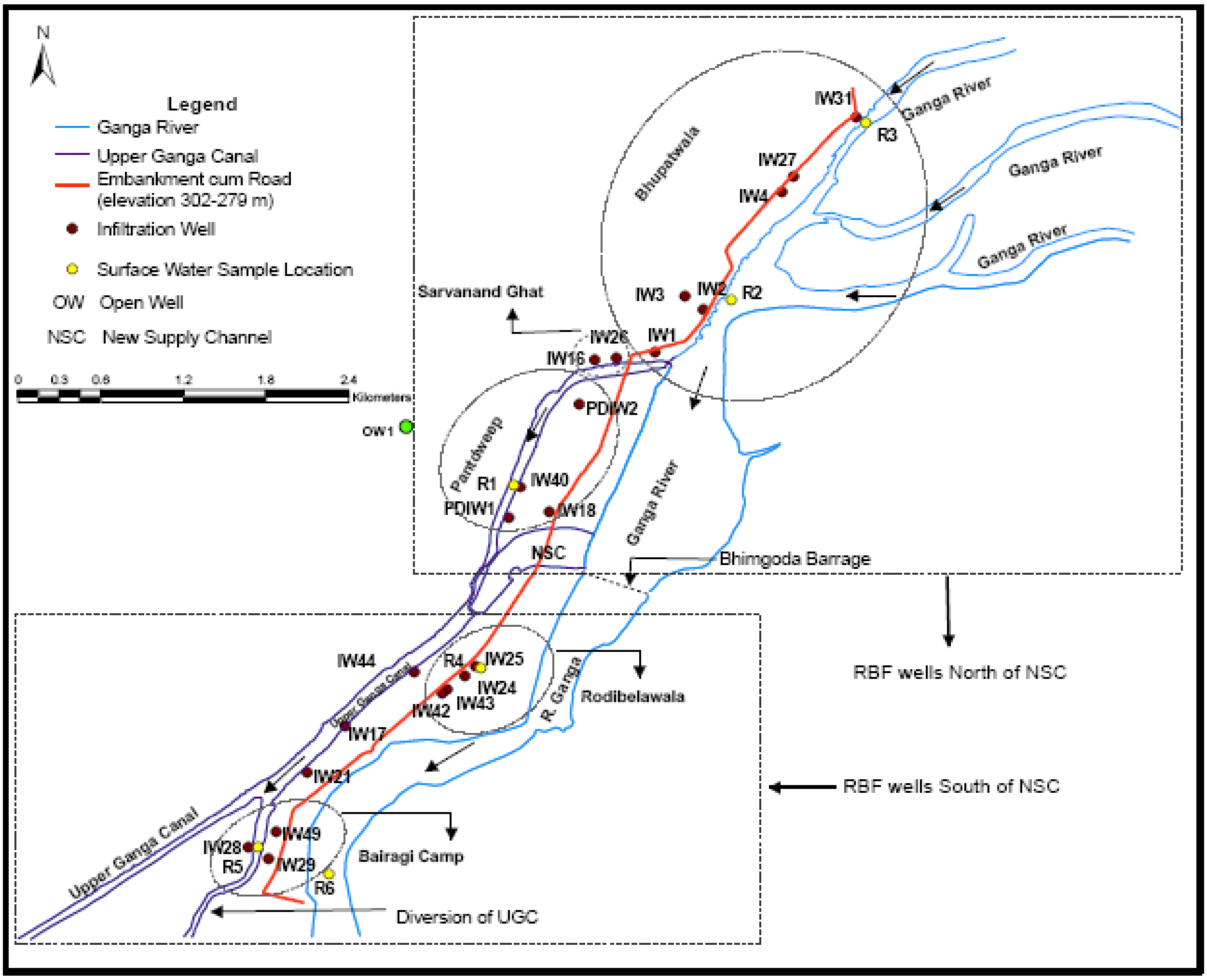

Figure 1 Location of BF wells and surface water sampling points in Haridwar (Saph Pani D1.2, 2013)

The only post-treatment applied to the water abstracted from these production wells is disinfection by using sodium hypochlorite (NaClO). Each production well (caisson well or tube well) has its own NaClO dosing system/pump. Adequate stock of 12.5% sodium hypochlorite solution (for 2- 3 weeks) is maintained at each production well or dosing point.

The operators are provided with a dosing chart/table for estimating the pumping rate of hypochlorite dosing pump depending upon the capacity of the well or size of the reservoir. (see Appendix A for an example). Sodium hypochlorite is injected (using a dosing pump) directly into the distribution pipeline immediately after the abstraction pump. However, when the disinfectant dosing pumps are defunct or non-existent, NaClO is directly poured manually into the caisson wells or into water storage tanks/reservoirs.

Figure 2 Typical sodium hypochlorite dosing system for RBF wells in Haridwar

During the field visit (in December 2013) it was observed that most of the production wells do not have sampling point after the dosing of the disinfectant. Therefore, the concentration of the residual chlorine in water (amount dosed) can be estimated by calculations only. The objective of the disinfection in Haridwar is to achieve the residual chlorine dose of 0.5 mg/L at the initial stage and to maintain a residual of 0.2 mg/L at the consumer point. Residual chlorine concentration is measured daily from 10 locations (selected randomly) of 3 zones of the distribution system regularly and sodium hypochlorite dose is changed at some points if required. Sometimes hypochlorite solution is also dosed in to the reservoir or overhead tanks specifically when the dosing pumps are not working and when the residual chlorine in certain area is lower than required value (0.2 mg/L).

2.1.2 Summary of the water quality analysis during Saph Pani sampling campaigns

Water samples were taken from the Ganga river, the upper Ganga canal as well as different production wells during 2 different sampling campaigns. The results of water quality analysis are presented in detail in Saph Pani D4.2 (2013) and D4.3 (2014). An overview of typical major water quality parameters of raw water and bank filtrates at case study site Hardiwar is presented in Table 1.

It was observed that bank filtrate is generally of very good quality. Occasional presence of relatively higher number of *E.coli* and *Total Coliform* is the only water quality concern for the BF wells in Haridwar. All other water quality parameters of the water from production wells are meeting the local water quality requirements. The bank filtrate, therefore, only requires disinfection before supply.

Table 1 An example of major water quality parameters of source water and bank filtrates at bank filtration site Haridwar (UJS, 2012)

Water Quality Parameters	Raw Water		Abstracted Water From Production Well					
	Canal	River	IW-16	IW-17	IW-18	IW-21	IW-29	IW-31
Turbidity (NTU)	240	167	0.40	0.15	0.33	0.27	0.21	0.19
Electrical conductivity (µS/cm)	150	179	510	306	429	239	294	507
Total dissolved solids (mg/L)	104	120	343	212	296	165	206	350
Suspended solids (mg/L)	79	105	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
pH	8.1	8.2	8.1	8.2	7.9	8.2	8.2	8.0
DO (mg/L)	8.6	8.7	2.5	3.9	4.9	4.1	4.9	4.6
Total Hardness (mg/Las $CaCO_3$)	72	88	220	144	208	112	144	232
Ca^{2+} (mg/L as $CaCO_3$)	56	52	58	124	166	74	98	174
Mg^{2+} (mg/L as $CaCO_3$)	16	36	162	20	42	38	46	58
Na^{+} (mg/L)	2.7	3.1	15.8	6.9	7.6	4	4.5	19.3
K^{+} (mg/L)	2.7	2.7	5.5	3.5	7.3	3	4.4	3.8
HCO_3^{-} (mg/L as $CaCO_3$)	58	72	206	112	176	82	114	236
SO_4^{2-} (mg/L)	22.2	23.6	24.2	19.3	24.7	17.8	22.1	13.6
Cl^{-} (mg/L)	1	1	24	16	18	10	9	18
Total Coliform (MPN/100 mL) 48 hrs	16000	9000	80	50	23	23	23	23
Fecal Coliform (MPN/100 mL)	16000	5000	<2	4	<2	<2	<2	<2

Note: IW = Infiltration Well, N.D. = No detectable;

2.1.3 Recommendations for case study site Haridwar

Based on the observations made during the field study and the results of the water quality analysis during different sampling campaigns the following is recommended:

1. A system should be in place to check the quality of the disinfectant stock solution and the amount of disinfectant dosed (by taking regular samples) and disinfectant doses should be adjusted accordingly, if required.
2. The present practice of dosing sodium hypochlorite solution directly into the caisson wells should be discontinued as it may also affect the production and pumping/pipe systems causing corrosion.
3. Leakage in the distribution system, corrosion of pipes and cross-connections are some of the problems in distribution system which may lead to higher doses of disinfectants and also influence the overall water quality at the consumer end. This area needs some attention to ensure that good quality bank filtrate water does not deteriorate or get contaminated in the water distribution system.

2.2 Case study site Srinagar

2.2.1 Overview of RBF system and existing post-treatment

Srinagar (in Uttarakhand) is located on the south bank of the meandering Alaknanda River. The combined drinking water production for Srinagar and the town of Pauri (the water for which is abstracted and treated in Srinagar before being pumped 29 km to Pauri) was around 3'750 m^3/day in 2010 while the demand has been estimated as 4'880 m^3/day (Kimothi et al., 2012). According to Saph Pani Deliverable D1.2 (2013) around 80 – 82% of the total raw water for the drinking water supply of Srinagar and Pauri is abstracted upstream of the town directly from the Alaknanda River. The abstracted surface water is first coagulated with alum and then flows to sedimentation tanks followed by rapid sand filters and is finally chlorinated before being supplied to the distribution network.

As described in the Saph Pani Deliverable D1.12 (2013), in May 2010, one production and one monitoring well (PW-DST & MW1, Figure 3) were constructed in the South-West part of the town as part of a separate project by UJS (Ronghang *et al*., 2011; Kimothi *et al*., 2012). These wells are located 170 m from the riverbank and were drilled up to a depth of 20 m.

Water Quality Concerns at Srinagar

During the monsoon season the Alaknanda river exhibits high turbidity which cannot be removed in the existing surface water treatment plant by conventional processes. The bacteriological contamination of the river, in terms of the most probable number of total and fecal coliform counts, ranges from 350 MPN/100 mL to 79×10^3 MPN/ 100 mL and from 1.6×10^3 MPN/100 mL to 17×10^3 MPN/100 mL, respectively (Sood *et al*., 2008; Sandhu *et al*., 2011a).

Figure 3 Production well at RBF site in Srinagar (top) by the Alaknanda River in Uttarakhand operated by UJS, the disinfection dosage pump (bottom left) and the disinfectant supply pipe (bottom right) to the drinking water distribution pipe from the well (Photos: HTWD, 2013; Installation of disinfection system: courtesy SME Simplex Control Equipments**)**

Preliminary hydrogeological investigations in 2009 – 2010 have shown promising conditions for developing RBF in Srinagar (Sandhu *et al*., 2011a). A very low turbidity and no indication of bacteriological contamination in the water abstracted by two existing drinking water production wells located 39 m and 240 m from the river bank (constructed in Deen Dayal Park and Silk Farm in 2006) was reported. Subsequently, another production and one monitoring well were constructed in the south-west part of the town in May 2010, at a distance of 170 m from the river bank (Kimothi *et al*., 2012). The objective of these wells is to investigate the potential of RBF for improving the existing water quality and quantity of the drinking water supply to Srinagar and Pauri town located 29 km from Srinagar (Ronghang *et al*., 2011; Kimothi *et al*., 2012). After abstraction of water from the production well and on-site disinfection using sodium hypochlorite (Figure 3), the water is pumped into a storage reservoir and then supplied into the distribution network by gravity. Water quality investigations of the production well in operation since 2010 have shown that nitrate concentration is in the range of 53 – 123 mg/L in the abstracted water (Ronghang *et al*., 2011). Although the mean hardness concentration monitored since 2010 is 439 mg/L as $CaCO_3$, it however lies within the permissible limit of 600 mg/L in the absence of an alternative drinking water source. Thus the main parameters of concern for post-treatment are the occasional presence of coliforms in very low numbers (prior to disinfection), and high nitrate concentrations (>50 mg/L) in the abstracted water.

2.2.2 Summary of the water quality analysis during Saph Pani sampling campaigns

Water samples were taken from river, as well as the RBF well (Figure 3) during 2 different sampling campaigns. The results of water quality analysis are presented in detail in Saph Pani D4.2 and D4.3. An overview of typical major raw water and treated water quality parameters at case study site Sri Nagar is presented in Table 2.

It is to be noted that concentration of the nitrate in bank filtrate is higher than that in the surface water. The nitrate concentration in the RBF well water has been consistently above the permissible limit of 45 mg/L for drinking water (IS 10500: 2012). The possible source of this nitrate seems to be some of the bedrock in the region, which is leaching nitrate in the groundwater. Nitrate is not the major concern in the water supplied at present, as the water is mixed with treated surface water before supply. However, several new bank filtration wells could be constructed in Srinagar in future, which may also give relatively higher concentration of nitrates. In that case some systems for removal of nitrates from bank filtrates (e.g. ion exchange, biological denitrification, reverse osmosis or electrodialysis) may be required (depending upon the dilution ratio with the water from surface water source).

Table 2 An example of major water quality parameters of source water and bank filtrates at bank filtration site Srinagar (UJS, 2012)

Water quality Parameters	**Raw water**	**Bank filtrate**	**Desirable Limit per Indian Standard IS 10500 (2012)**
pH	8.1	7.4	6.5 to 8.5
Turbidity (NTU)	12	<1	5 max
Total dissolved solid (mg/l)	110	650	500 max
As (mg/l)	<0.005	<0.005	0.01
F^- (mg/l)	0.2	0.2	1
Cl^- mg/l	28	75	250
PO_4^{3-} (mg/l)	0.2	0.3	0
NO_3^- (mg/l)	8	**55**	45
SO4),mg/l	15	88	200
Fe (mg/l)	0.12	0.06	0.3
Total Hardness (as CaCO3) (mg/l)	78	**470**	300
Mg (mg/l)	12	**41**	30
Mn (mg/l)	<0.01	0.01	0.1
Zn (mg/l)	0.03	0.05	5
Na (mg/l)	13	45	0
K (mg/l)	2	15	0
Pb (mg/l)	<0.01	<0.01	0.05
Electrical conductivity (µmhos/cm)	166	986	Not specified
Phenolic compound (as C_6H_5OH) (mg/l)	<0.001	<0.001	0.001
Fecal coliforms (MPN/100 ml)	900		10

2.2.3 Recommendations for case study site Srinagar

The RBF well constructed in Srinagar in 2010 with DST support (PW-DST; Fig. 3) has been consistently delivering water with most parameters within the desirable limits as per the Indian Standards 10500 (2012), except two parameters — total coliform (TC) and nitrate (Saph Pani D1.1, 2012; Saph Pani D4.3, 2014). A TC count of ~3000 MPN/100 mL was detected once in the monsoon of 2012, but at other times of the year, no coliforms were detected in the well water (Saph Pani D4.3, 2014). Thus, based on the observations made during the field study and the results of the water quality analysis during different sampling campaigns the following is recommended as outlined in Saph Pani Deliverable D4.3 (2014):

1. *Changing operational design and pumping conditions:* It is possible to lower the nitrate concentration to within the permissible limits by increasing the pumping rate. This modification will increase the portion of young bank filtrate and decrease the proportion of groundwater and old bank filtrate originating from upstream part of the town (Saph Pani D1.2, 2013). But as the pumping rate cannot be increased beyond a certain limit for the PW-DST, the portion of young bank filtrate flowing to the PW-DST well can further be increased by installing more wells nearby. The RBF wells at a well-field in Dresden-Tolkewitz, Germany, which was visited during the Saph Pani Indo-European exposure tour, also had a high nitrate concentration because of high nitrate in the land-side groundwater (Grischek *et al*., 1996). Defining a certain pumping rate to optimize the portion of bank filtrate helped in reducing the nitrate level in the abstracted water at that particular site.
2. *Mixing with other water:* Srinagar currently also has a conventional water treatment plant which directly uses the river water and treats it by coagulation-flocculation, rapid sand filtration and disinfection before distributing it. Mixing RBF well water with this water from the conventional treatment plant can bring down the nitrate concentration in the water supply.
3. *Installation of nitrate treatment units:* Post-treatment systems using technologies such as ion exchange, reverse osmosis, electrodialysis, biological denitrification and chemical denitrification can be used for nitrate removal. However these are comparatively less attractive than option 1 and 2, especially in the mountainous state of Uttarakhand because they are expensive, require significant amount of maintenance and operational know-how and generate large volumes of residues. Furthermore, they require a largely uninterrupted power supply which is extremely difficult to provide year-round in Uttarakhand particularly when the hydropower generation decreases during monsoon (June – September, due to very high suspended sediment load in surface water) and low-flow periods (December – February).

2.3 Case study site Nainital

2.3.1 Overview of BF system and existing post-treatment

UJS utilises water from the Naintal lake as a source of supply employing BF technology to supply water to the city of Nainital. The proportion of lake water being pumped from seven vertical filter wells (installed in 1990 – 2007) located near the lake was estimated by isotopic tracer technique (Nachiappan *et al*., 2002). The results show that the proportion of the lake water in the water pumped from wells is lower in non-monsoon season (25–40%) as compared to monsoon season (80%).

Disinfection using bleaching powder is the main post-treatment step in Nainital. The operators are provided with a chart/table for estimating the amount of bleaching powder to be added per day. There are standard size tanks for feeding bleaching powder and the preparing solution which is dosed by hydraulic method with an overflow weir (without a pump). 2 kg of bleaching powder is added every hour to a 2000 L tank to obtain bleaching powder concentration of 2 mg/L. With 25% chlorine content of the bleaching powder, the estimated chlorine at the initial stage is 0.5 mg/L. Bleaching powder is dosed at 5 locations in the water supply system, namely in the (i) Main pump house, (ii) Children park pump house, (iii) Phasi gadera, (iv) Sukhatal tube well and (v) Sukhatal old water works. After bleaching powder solution dosing, the residual chlorine content in the reservoirs (before supplying water to the distribution system) is not measured. Samples are however taken from different points in the distribution system to monitor residual chlorine concentrations.

There is an ion-exchange system for water softening at Mallital pumping station (near the Children Park) at which about half of the total production at this site is treated and then two streams are mixed again before disinfection and supply (see Figure 4). It was reported by the operators that the ion exchange system is not operated regularly because of the high costs. A new ion-exchange treatment system for hardness removal is under construction (near the main pump house) under the Asian Development Bank project.

There is rapid clogging and failures of the water meters due to high hardness in water. Water meters in some areas need frequent cleaning or even replacement.

Water quality concerns at Nainital

Dash *et al*. (2008) reported the hardness of the production well water in Nainital ranged from 370 to 434 mg/L (as $CaCO_3$). As per the Indian standards (IS 10500: 2012), desirable limit for hardness is 300 mg/L (as $CaCO_3$). However, in the absence of an alternate source, hardness is permissible up to 600 mg/L (as Ca CO_3). Temporary hardness (i.e. carbonate) was 3–5 times the permanent (i.e. non-carbonate) hardness in bank-filtered waters collected from different production wells. TDS, electrical conductivity, calcium, magnesium, sodium, potassium, bicarbonate, chloride and sulphate were found to be more in production well water than in the lake water. Ammonia, phosphorus, organic matter and total coliform were higher in lake water than production well water. Total and fecal coliform were not detected in any of the production well water samples both during monsoon and non-monsoon seasons. It was concluded that lake water as such was not potable as it contained unacceptable levels of organics, coliforms and nutrients.

In Nainital, all BF wells except one (PW3-old) have been consistently giving good quality water. Well 3 (PW3-old) gives water with high turbidity. Therefore, it is not used for abstracting water for supply. In other wells, total coliforms as well as fecal coliform counts are below the detection limit of 2 MPN/100 mL. Sometimes during monsoon season, the total coliform count in one or two wells is ~7 MPN/100 mL. This level of pathogens is easily treated with the chlorination of water that is being currently done on-site at the waterworks before distribution.

Occasionally, Ca^{2+} concentration in some of wells farther away from the lake increases above the acceptable limit of 75 mg/L (IS 10500 : 2012), but remain lower that the permissible limit of 200 mg/L in absence of alternate source of water. Concentration of Mg^{2+} is often above the acceptable limit of 30 mg/L, but is also below the permissible limit of 100 mg/L. Since the water abstracted from several wells is mixed in two reservoirs at the waterworks before distribution, the ions concentrations also get averaged.

Figure 4 Ion-exchange water softening system treating bank filtrate at Nainital

2.3.2 Summary of the water quality analysis during Saph Pani sampling campaigns

Water samples were taken from sources and tube wells wells during 2 different sampling campaigns. The results of water quality analysis are presented in detail in Saph Pani D4.2 and D4.3 (2013). An overview of typical major raw water and treated water quality parameters at case study site Nainital are presented in Tables 3 and 4 respectively.

Table 3 An example of major water quality parameters of source water at BF site Nainital (UJS, 2012)

Water Quality Parameters	TW1	TW2	TW3	TW4	TW5	TW6	TW7	TW8	TW9	Spring	Sukhatal TW
Turbidity (NTU)	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Phosphate (mg/L)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
pH	7.96	8.08	7.95	7.78	8.07	7.81	7.9	7.88	7.9	8.25	7.8
Alkalinity (mg/L)	320	240	244	252	302	280	280	320	292	316	280
Dissolved oxygen (mg/L)	6	6.1	7	6.4	7.2	6.4	5.6	5	5.2	7	5.8
Chloride (mg/L)	12	16	12	14	24	26	14	24	26	18	10
Nitrate (mg/L)	Nil	0.5	0.5	0.5	2	Nil	Nil	1	1	1.5	1
Nitrite (mg/L)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Iron (mg/L)	Nil	Nil	Nil	0.05	0.04	0.05	Nil	0.1	0.05	Nil	Nil
TDS (mg/L)	466	452	466	472	508	518	540	588	602	556	520
Total Hardness (mg/L $CaCO_3$)	360	399	388	324	399	432	414	446	480	396	498
Ca++ Hardness (mg/L $CaCO_3$)	162	180	151	148	184	192	198	216	224	210	234
Mg++ Hardness (mg/L CaCO3)	192	219	237	176	215	240	216	230	256	186	234
Sulphate (mg/L)	125	115	125	137	150	150	150	175	175	132	152
Total and fecal coliform	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Note: TW = Tube Well

Table 4 An example of major water quality parameters of treated water at case study site Nainital

Water Quality Parameters	Near CWR Main Pump House	Near CWR Children Park	Spring	Sukhatal CWR
Turbidity (NTU)	1.9	2	2	<5.00
Phosphate (mg/L)	Nil	Nil	Nil	Nil
pH	8	8.2	8.2	8.18
Alkalinity (mg/L)	300	304	294	288
Dissolved oxygen (mg/L)	9.4	9.2	9.6	7.6
Chloride (mg/L)	18	22	22	12
Nitrate (mg/L)	4	3.5	3.5	2
Nitrite (mg/L)	Nil	Nil	Nil	Nil
Iron (mg/L)	Nil	Nil	Nil	Nil
TDS (mg/L)	498	510	502	594
Total Hardness (mg/L $CaCO_3$)	**410**	**412**	**398**	**448**
Ca++ Hardness (mg/L $CaCO_3$)	178	168	184	188
Mg++ Hardness (mg/L $CaCO_3$)	232	244	214	260
Sulphate (mg/L)	112	140	128	120
Total and fecal coliform (MPN/100 ml)	Nil	Nil	Nil	Nil
Residual Chlorine (mg/L)	0.4	0.4	0.2	0.4

Water quality analysis showed that the relatively high hardness of the bank filtrate is one of the water quality concerns at Nainital. It is expected that this problem can be addressed if the existing softening plant is operated continuously and the new softening plant which is currently under construction is put into operation.

2.3.3 Recommendations for case study site Nainital

Based on the observations made during the field study and the results of the water quality analysis during different sampling campaigns the following is recommended:

1. A system should be in place to check the quality of the bleaching powder and the dosage (by taking regular samples). Disinfectant dosage should be adjusted accordingly, if required.
2. Leakage in the distribution system, corrosion of pipes and cross-connections are problems in the water distribution system which may influence the water quality. Some of galvanized iron (GI) pipes in the system are 30-40 years old. The distribution system is flushed when there is complaint about water quality from the consumers. This area needs some attention to ensure that good quality bank filtrate water is not deteriorated in the distribution system.
3. A proper hardness removal system should be included in the post-treatment scheme of Nainital BF system which is currently only limited to disinfection by bleaching powder and occasional operation of a few ion-exchange units.
4. It is to be noted that the existing and proposed ion-exchange system for hardness removal will require skilled operation and adequate/additional O&M budget for regeneration and replacement of the media as required. Use of alternative water sources with lower hardness together with the management of the pumping regime of the tube wells could be an option to reduce the overall hardness in the water supplied.

3. Recommendations for BF Case Study Site Delhi

3.1 Overview of BF case study site Delhi and summary of water quality analysis

Description of the field site: The field site is located in the city center of Delhi on the East bank of the Yamuna River. Here, the undeveloped flood plain has a width of about 2.4 km. As along the whole Delhi stretch of the Yamuna River, the main aquifer at the field site is the shallow flood plain aquifer, also known as Newer Alluvium, which is underlain by clays and silts of the Old Alluvium. In the study area the New Alluvium has a depth of about 20 m and consists of mostly medium-grained sands. A gravel layer up to two meter thick is found at the bottom of the aquifer in most drillings in that area. Four large diameter radial collector wells (Ranney wells) as well as tube wells of the municipal water supplier Delhi Jal Board (DJB) are located on the undeveloped flood plain in the study area and tap the shallow aquifer. Furthermore a Ranney well of the Indian Railways Company and numerous hand pumps and small scale bore wells of the local people draw water from the aquifer in that area.

Water samples and analyses: Previous research at this location was conducted in 2006 in the frame of the feasibility study IDB India (International Development of Bank Filtration: Case study India) and 2007-10 in the frame of the TECHNEAU project (EU grant agreement number 018320) (Lorenzen *et al*. 2007; Sprenger *et al*. 2008; Lorenzen *et al*. 2010, Pekdeger et al. 2008). Ammonium, fluoride, iron, manganese and arsenic were identified as the critical parameters during those studies (Pekdeger *et al*. 2008).

During Saph Pani project, 68 groundwater samples have been taken from the sampling points as shown in Figure 5. The analyzed water quality parameters relevant for the Indian Standard Drinking Water Specification (IS 10500:2012) are summarized in Table 5. In accordance with the previous studies, the parameters of concern identified in the water from the Ranney wells are ammonium, fluoride, iron, manganese and arsenic. Furthermore, Ca and total alkalinity concentrations exceed the acceptable limits in all samples taken from the Ranney wells, however, concentrations still are below the permissible limits of 200 mg/L and 600 mg/L respectively. Sulphide concentrations above the permissible limits were found in only one sample taken from the Ranney wells.

Table 5 Indian drinking water quality limits compared to the analyses of water samples taken from the flood plain aquifer at the Nizamuddin field site, Delhi.

Parameter	Acceptable limit according to IS 10500:2012 (requirement) [mg/L]	Permissible limit [mg/L] according to IS 10500:2012	Concentrations found in Ranney wells [mg/L]	Concentrations found in handpumps and observation wells [mg/L]
Al	0.03	0.2	0 - 0	0 - 0.1
Ammonium	0.5	0.5	0.2 - 8	0.05 - 35
Ba	0.7	0.7	0 - 0.43	0.16 - 0.78 (2.27)
B	0.5	1.0	0 - 0.09*	0 - 0.1*
Ca	75	200	80 - 107	54 - 138
Cl	250	1000	52 - 175	(6)39 - 232
F	1.0	1.5	0 - 5	0.1 5
Fe	0.3	0.3	0 - 2.7	0 - 22.3
Mg	30	100	19 - 32.8	14 - 40.1
Mn	0.1	0.3	0.3 - 0.7	0.06 - 2.7
NO_3	45	45	0 - 10	0 - 85
SO4	200	400	5 - 122	0 - 175
Sulphide (as H_2S)	0.05	0.05	0 – 0.11**	0 - 0.06 HS**
Total alkalinity (as $CaCO_3$)	200 (4 mmol/L***)	600 (12 mmol/L***)	240-445*** (4.8 - 8.9 mmol/L)	370- 725*** (7.4 - 14.5 mmol/L)
As	0.01	0.05	0 - 0.108	0 - 0.146

Note: Concentrations 0 mg/L refer to concentrations below the detection limit.

*Boron was not analyzed in all samples taken during the sampling campaigns

** Sulphide test-kit did not work for all samples; all but one samples taken from the Ranney wells had sulphide concentrations equal or below 0.02 mg/L

*** If calculated with a molar weight of 50.04 mg/mmol (1 mmol/L H^+ ≡ 0.5 mmol/l $CaCO_3$ ≡ 50.04 mg/L $CaCO_3$)

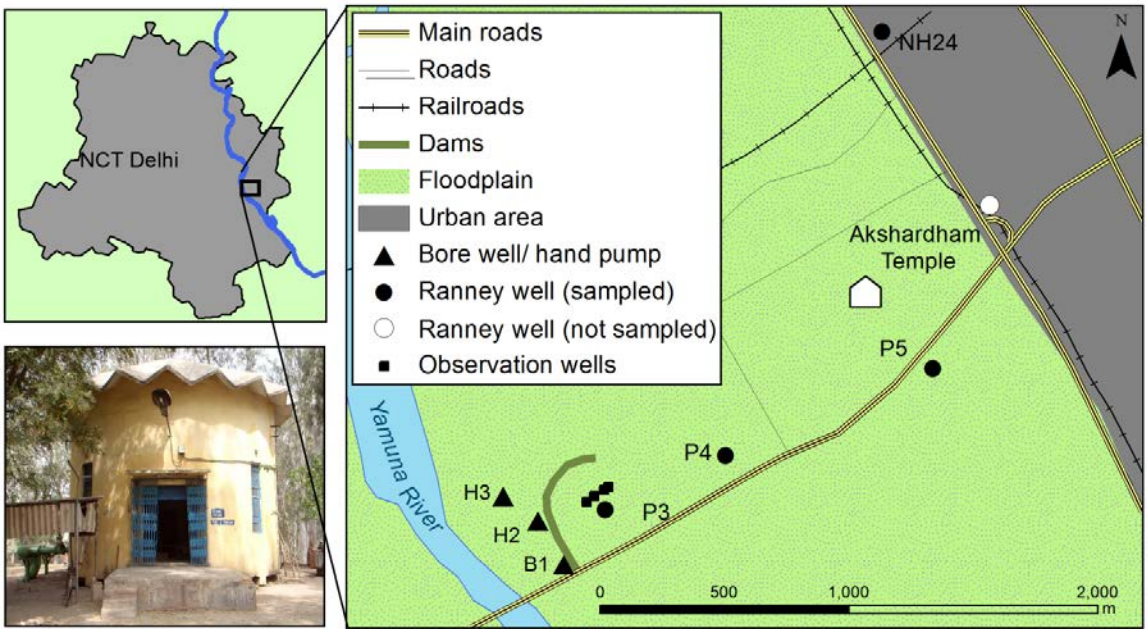

Figure 5 Ranney well (P3); b. Location of the study are and the sampling points (modified after Groeschke 2006)

Additionally two sets of samples were taken in July 2013 and December 2013 respectively at this case study site to screen the presence of organic micropollutants (OMPs) in Yamuna river water and their attenuation during the soil passage. Table 6 and 7 present the results of analysis of 39 selected micropollutants (including, pharmaceuticals and artificial sweeteners).

It was found that the Yamuna river contains traces of several OMPs (likely due to the impact of wastewater effluents discharged into it), which are however partially or fully removed during the soil passage. Most of the OMPs analyzed are below the detection limit in groundwater samples. This is clearly indicating that there is high degree of removal of OMPs during bank filtration.

Table 6 Concentrations of OMPs in samples taken at BF site Delhi (July 2013)

	Parameter	Surface water SW8 (ng/L)	GW well 200 m H2 (ng/L)	GW well 500 m obs_d (ng/L)
1	Benzotriazol	34		
2	4-Methylbenzotriazol			
3	5-Methylbenzotriazol			
4	Bezafibrate			
5	Carbamazepine	28	34	12
6	Clofibricacid			
7	Diazepam			
8	Diclofenac	78	98	
9	Etofibrate			
10	Fenofibrate			
11	Ibuprofen	72		
12	Indomethacin	13		
13	Naproxen	18		
14	Paracetamol			
15	Pentoxifyllin			
16	Betaxolol			
17	Bisoprolol			
18	Clenbuterol			
19	Cyclophosphamid			
20	Dimethylaminophenazone			
21	Ifosfamide			
22	Metoprolol			
23	Phenazon			
24	Propranolol			
25	Salbutamol			
26	Simvastatine			15
27	Sotalol			
28	Amidotrizoicacid	41		
29	Iohexol	270		
30	Iopamidol	17		
31	Iopromide	12		
32	Iotalamicacid			
33	Ioxaglicacid			
34	10,11-Dihydro-10,11-dihydroxycarbamazepin	75	90	
35	Acesulfame	70	40	
36	Cyclamate			
37	Saccharine			
38	Sucralose			70

Note: Blank = < Detection limit; ** Detection limit for all compounds except Sucralose = 10 ng/L; *** Detection limit for Sucralose = 50 ng/L

Table 7 Concentrations of OMPs in samples taken at BF site Delhi (December 2013)

	Parameter	Surface water SW10 ng/L	GW well 200 m H1 ng/L	GW well 500 m Obs_b ng/L
1	Benzotriazol		1800	
2	4-Methylbenzotriazol		260	
3	5-Methylbenzotriazol		99	
4	Bezafibrate			
5	Carbamazepine			
6	Clofibricacid			
7	Diazepam			
8	Diclofenac	630	100	230
9	Etofibrate			
10	Fenofibrate			
11	Ibuprofen	1500		
12	Indomethacin	11		
13	Naproxen	110		
14	Paracetamol	94	16	< 10
15	Pentoxifyllin			
16	Betaxolol			
17	Bisoprolol			
18	Clenbuterol			
19	Cyclophosphamide			
20	Dimethylaminophenazone			
21	Ifosfamide			
22	Metoprolol	76		
23	Phenazone			12
24	Propranolol			
25	Salbutamol	27		11
26	Simvastatine			
27	Sotalol			
28	Amidotrizoicacid	510		
29	Iohexol	2400		
30	Iopamidol	170		
31	Iopromide	130		
32	Iotalamicacid			
33	Ioxaglinacid			
34	10,11-Dihydro-10,11-dihydroxycarbamazepine	530	88	450
35	4-Acetylaminoantipyrin	33		
36	4-Formylaminoantipyrin	22		30
37	Acesulfame	300	30	220
38	Cyclamate	70		
39	Saccharine	4000		
40	Sucralose	520		170

Note: Blank = < Detection limit; ** Detection limit for all compounds except Sucralose = 10 ng/L; *** Detection limit for Sucralose = 50 ng/L

3.2 Description of post-treatment at Okhla WTP Delhi

The water from the DJBs Ranney wells P3 and P5 is distributed to the Okhla treatment plant, where it is mixed with water from other sources (Ganges water) before treatment and then pumped into distribution network of south Delhi. The capacity of Okhla water supply works is 23'000 m^3/day. A schematic of the treatment process applied is presented in Figure 6.

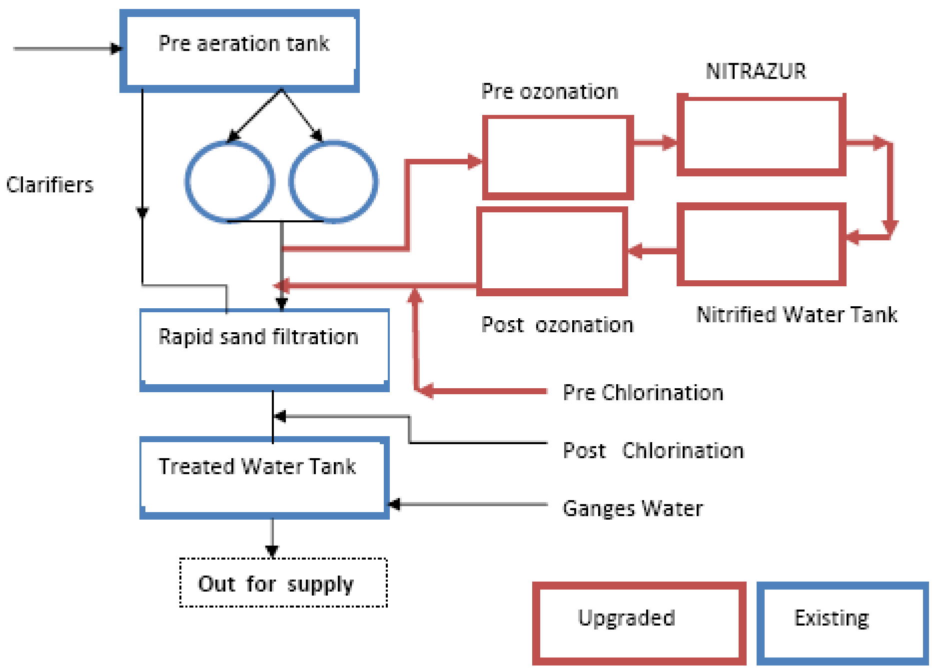

Figure 6 Schematic of treatment process at Okhla WTP, Delhi

The red marked up-gradation of post treatment is done for a single stream of 23'000 m^3/dayonly; thereafter it is mixed with the other stream of 23'000 m^3/day and then chlorinated and finally mixed with the Ganges water and distributed as potable supply.

The upgraded treatment process consists of three main steps namely (i) pre-ozonation, (ii) nitrification and (iii) post-ozonation. In the pre-ozonation step, a small dose of ozone, around 0.3 ppm, is added to the incoming water so as to kill any microorganisms present. This step is carried out in order to prevent the growth of unwanted microorganisms in the subsequent biological nitrification process. The nitrification step consists of biological oxidation of dissolved ammonia present in water into nitrates in the presence of air, using nitrifying bacteria. The nitrification process is carried out in up flow aerated NITRAZUR filters packed with a special media on which nitrifying bacteria attach themselves.

In the post-ozonation step, a higher dose of ozone, around 1.0 mg/L, is added to the nitrified water. Ozonation also improves the organoleptic qualities of water, i.e. organic matter levels, taste and odour and residual organic impurities are destroyed. However, ozonation does not completely eliminate the need for chlorination. Finally some chlorine addition, in vastly reduced quantity, is done to ensure presence of residual chlorine in water supplied to consumers.

Presence of ammonia in water requires a high chlorine dose of around 8 ppm in post-treatment. Removal of the same before chlorination is to be done through ozonation & nitrification before post treatment.

Due to increasing pollution in Yamuna & Ganges water, ammonia concentration is expected to increase in future; and upgraded post-treatment may be required for the other 23'000 m3/day stream too

Water from Ranney well P4 and from several tube wells located near the field site is treated in the Common Wealth Games Village Water Treatment Plant. This treatment plant is designed for 4'000 m3/day and is operating since 2010. The water is treated in several steps. After aeration and coagulation/flocculation steps, ultrafiltration is applied followed by ozonation and chlorination.

3.3 Recommendations for post-treatment of water from BF site Delhi

Previous studies at the case study site in Delhi as well as sampling campaigns during Saph Pani have shown that presence of elevated level of ammonium, nitrate, arsenic, fluoride, iron and manganese are the main water quality concerns for wells in the area. Furthermore, source water samples (Yamuna river) also showed the presence of some organic micropollutants which are substantially removed during the soil passage. Traces of some organic micropollutants were also found in samples from observation wells and handpump.

The water abstracted from the production wells (Ranney wells) around this site is mixed with the surface water from other sources and treated extensively at full-scale treatment plants (e.g. Okhla WTP and Common Wealth Games WTP). No major water quality problems are expected. People using hand pumps or tube wells in this area are however recommended to use household level ammonium, nitrate, arsenic and fluoride removal system to ensure that water from these local wells are meeting the drinking water quality requirements. Furthermore, water authorities using water production wells around the case study sites for municipal water supply are recommended to monitor the presence of OMPs in the well waters and in the treated water, to ensure that these pollutants are sufficiently removed during the treatment process.

4. Recommendations for Post-treatment of Groundwater Wells Around Periapalayam Check Dam, Chennai

4.1 Overview of case study site Periapalayam check dam, Chennai and summary of water quality analysis

The Arani River is a seasonal river and carries water only during the monsoon period which is about 60 days per year. The village next to the investigated check dam is called Periapalayam and is located about 40 km north of Chennai. It is a rural area with intensive agriculture activities. In addition, several big industrial companies are also located in the region. As there is a famous temple close to the river, many devotees are visiting each year. The temperature of this area vary from 38°C to 42°C during May-June and from 18°C to 36° C during December- January. Annual rainfall of 1200 mm is received during southwest (35%) and north east monsoon (65%).

In 2010 a check dam was constructed across the Arani river to augment the groundwater resources. The check dam has a length of 260 m and a height of 3.5 m and is able to store 0.8 million cubic meter of water.

Selected groundwater parameters as well as hydrological conditions in the check dam area have been investigated regularly by the Geology Department of Anna University since July 2010. In April 2013 a joint sampling campaign with FHNW was carried out and continued regularly until August 2013 by Anna University in order to investigate the influence of the check dam on groundwater quality. Groundwater samples were taken from two dug-cum bore wells and four deep bore wells in the area. Water quality parameters including chlorinated pesticides and insecticides, biological parameters as well as organic and inorganic parameters were measured in these samples. All sample locations and their distance to the check dam are listed in Table 8.

Table 8 Investigated bore wells in the Periapalayam check dam area

Sample ID	Location	Type	Depth [m]	Distance to check dam [m]
1	Watch tower	Deep bore well	30	150
2	Field / HW 1	Deep bore well	40	85
3	Rose field	Deep bore well	40	275
4	Hotel	Deep bore well	26	1000
5	Jasmine field	Dug-cum bore well	36	650
6	Friend house / HW3	Dug-cum bore well	19	85

The results of the measurements of selected physico-chemical water quality parameters as well as chlorinated pesticides and insecticides are displayed in Table 9. Compared to the WHO Guidelines (2011) the results indicate that the groundwater quality is relatively good. All measured values are in the range, except for turbidity.

Table 9 Results of sampling campaign Periyapalayam check dam April to August 2013

	1 (n=4)	2 (n=3)	3 (n=4)	4 (n=4)	5 (n=4)	6 (n=2)	Guideline values (WHO, 2011)
Atrazine [ng/L]	BDL	43	566	BDL	BDL	BDL	2 µg/L
TN [mg/L]	0.9-1.4	1.2-5	0.6-13	1.2-24	0.6-6	0.6-0.8	50 mg/L as NO_3^- , 3 mg/L as NO_2^-
TP [mg/L]	BDL-1.1	BDL-0.4	BDL-2.7	0.4-1.7	BDL-3	BDL-0.04	-
F* [mg/L]	0.5	0.3-0.5	0.1-0.4	0.2-0.4	0.4-0.6	0.4-0.6	1.5 mg/L
Fe [mg/L]	BDL-0.03	BDL	BDL-0.1	BDL-0.6	0.1-0.6	BDL	
Cl [mg/L]	BDL	BDL	BDL	BDL	BDL	BDL	5 mg/L
Mn [mg/L]	BDL-0.002	BDL	BDL	BDL-0.01	BDL-0.3	BDL	0.4 mg/L
Br [mg/L]	BDL-0.3	BDL-0.2	BDL-0.5	BDL-0.3	0.2-0.4	BDL-0.1	-
SAC [-]	1-2.6	0.6-3.7	< 0.5-2.1	0.7-3.3	0.1-2.4	< 0.5	-
DO [mg/L]	4.2-7.8	4.5-5.7	4.6-7.5	5.5-6	3.9-5.8	5.9-6.1	-
Salinity [ppt]	0-0.2	0-0.2	0-3	0-14	0-3.8	0-0.1	-
Turbidity [NTU]	0.1-0.7	0.4	0.1-5	0.1-1.3	0.1-3.2	0.7	< 0.1
pH	7.53-7.81	7.36-7.62	7-7.25	6.42-7.35	7.34-7.6	7.21-7.5	6.5 - 8.5
EC []	1461-1865	1046-1788	1921-2793	1151-1638	1290-1312	1672-2080	-
Temp. [°C]	29-30	29--30	26.67-29.3	29.93-31	28-29.3	29.2-30.8	-

All samples where measured by the C-tech laboratory in Chennai

* Measured by Anna University; BDL: below the detection limit

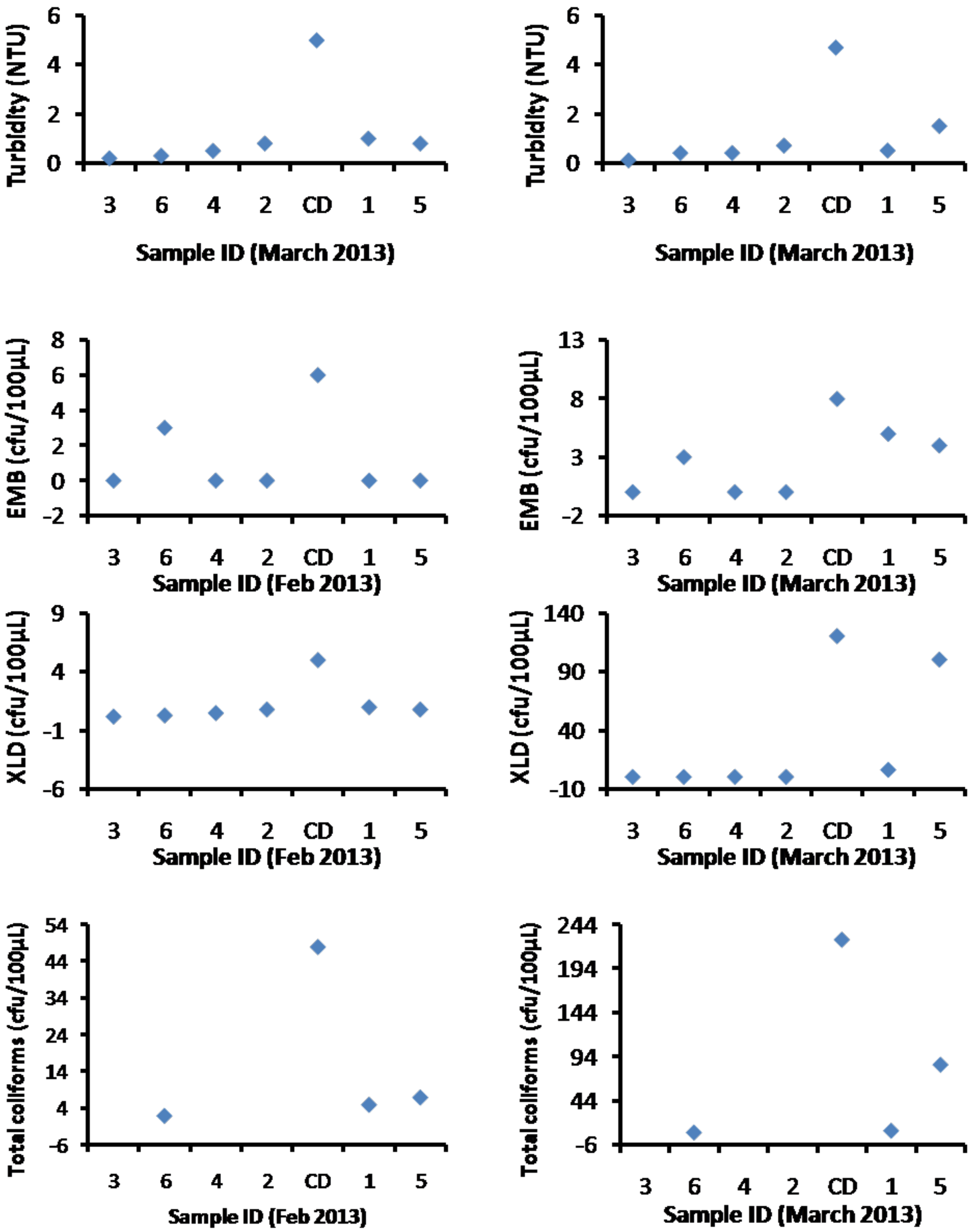

Figure 7 Reduction of turbidity and pathogens due to natural filtering process

Surface water stored by the check dam had very high turbidity and pathogens due to the collection of runoff from various land uses. In general the sources of bacterial pollution in surface water include runoff from woodlands, pastures, direct discharge of domestic and sewage waste, runoff from area's with highly populated animal and human settlement. When this water moves through the soil pores, three processes are taking place which include physical, chemical and biological processes. Due to these processes the surface water is treated and groundwater with less turbidity and less pathogens are obtained. The reduction in turbidity and pathogens when there was water in the check dam (February 2013 and March 2013) are shown in Figure 7. Among nine media, microbiological cultivation was present only in three selective media (Eosin methylene blue (EMB), Xylose lysine deoxycholate (XLD) and Thiosulfate-citrate-bile salts-sucrose (TCBS)).

4.2 Summary of the results of analysis two different post-treatment options

Groundwater is the major source of water supply worldwide. The availability and quality of groundwater, however, varies from place to place. Groundwater is generally a preferred source of water supply because of its relatively higher quality as the strata above serve as filter and offer protection from contamination. Excessive extraction of groundwater in the Chennai area has resulted in lowering of the groundwater level by several meters per year. The lowering of the water table in coastal regions leads to saline water intrusion into the drinking water aquifer (Grimm, 2008)

In a 3 month study a self-made saree filter (Figure 8) and a commercially available ceramic filter (Terafil filter, Figure 9) were tested to analyse their effectiveness in removal of pathogens from local groundwater. The saree filter was built after Colwell *et al.* (2003) and enhanced further with three layers of adsorption materials. The filter media used were stones, sand and coal (see Figure 8). Tests on the presence and removal of total coliforms and *E. coli* were carried out with the Colilert test kit from IDEXX.

Figure 8 Saree filter

Figure 9 Terafil Filter

Saree filter tests were conducted with several different (2-10) layers of cotton saree fabric. Regarding the test results of the saree filter system with respect to *E. coli* removal, only the test tubes which contained permeate from the 6 and 8 layer saree filters with sorption material showed a reduction of the *E. coli* contamination. 67% of the permeate samples from the 6 layer saree filter showed *E. coli* contamination. Permeate sample from the 8 layer saree filter did not show any contamination at all. This is an indication, that the 8 layer saree filter with sorption material was able to hold back the *E. coli* contamination successfully.

All filtrate samples from Terafil water filter showed contamination of coliform and *E. coli* bacteria. With a probability of 95% it can be said that the concentration of *E. coli* in the filtrate sample is above 8.0 cfu. This clearly shows that Terafil water filter tested was not effective in removal of *E. coli* from well waters. Furthermore, it is to be noted that although 8 layer saree filter was effective in *E coli* removal, further tests are required to check whether it could also remove the viruses or not.

4.3 Recommendations for post-treatment of groundwater from wells around Periapalayam check dam area, Chennai

The investigated abiotic water quality parameters (Table 9) show a relatively good water quality; only for pathogens and turbidity post-treatment options are needed. As bacterial contamination was found in nearly every sample location, it is obvious that microbiological parameters are the most critical for the potable use of groundwater in the check dam area.

As there were no spore producing organisms, the easiest and most relevant method of disinfection for this water is to boil it before drinking. Another possibility is chlorination or disinfection at household level. Chlorination tablets are available in the Periyapalayam area at a relatively low price. Regular dosage of chlorination tablets or chlorine solutions into the household water storage tanks can provide a stable disinfection effect in daily water usage. Other methods of household level treatment systems that could be effective for this particular site include solar-disinfection, ceramic filters or and bio-sand filters.

5. Summary and Conclusions

Of the three main soil-based NTSs namely BF, ARR and SAT, only BF has been used in India for municipal water supply. Managed aquifer recharge systems like ARR and SAT has not been employed as a part of integrated system at municipal or water supply utility level for treatment and subsequent reuse of surface water or wastewater treatment plant effluents. Based on the literature review, field data collection and analysis the following are the general recommendations for improvement of water quality and post-treatment at some of the case study sites of Saph Pani.

At the BF case study site Haridwar, bank filtrate is generally of reasonably good quality except for occasional presence of pathogen indicators. The current practice of disinfection with sodium hypochlorite should be sufficient to meet the drinking water quality requirements. It is recommended to monitor the amount of sodium hypochlorite dosed regularly by taking the water samples after dosing and adjust the dosage accordingly if required. Furthermore, the practice of dosing sodium hypochrite directly into the caisson well should be discontinued as it may affect the well and pumps.

High hardness in the bank filtrate is one of the main water quality concern at Nainital. The operation of the existing ion-exchange softening system should be regular to ensure that the hardness of the water supplied meet the water quality guideline values. It is expected that the current issue of hardness in supplied water will fully be taken care of by the introduction of the new softening plant presently being constructed at the main pumping station. In addition to the current practice of taking water samples from different parts of water distribution systems to analyze residual chlorine, it is also recommended to monitor the concentration of chlorine applied to the water by taking water samples from the reservoirs before supply.

Leakage together with the corrosion of the pipes in the distribution systems of Haridwar and Nainital should be given special attention as these two factors may lead to high chlorine consumption and deteriorate the quality of bank filtrate (which is often meeting the drinking water quality requirements).

Analysis of water quality of source water and wells at the BF case study site Delhi has shown relatively high concentrations of ammonium, nitrate, arsenic and fluoride and traces of some OMPs. As water from the production wells around this site is mixed with surface water from other sources and treated at full-scale treatment plants, no major water quality problems are expected in the water supplied. People using hand pumps or tube wells in this area are, however, recommended to use household level ammonium/nitrate, arsenic and fluoride removal system to ensure that water from these local wells are meeting the drinking water quality requirements. Furthermore, water authorities using production wells around the case study sites are recommended to monitor the presence of OMPs in the well water, to ensure that these substances are sufficiently removed during the treatment process.

A relatively high number of pathogen indicators is the main water quality concern for water from wells around Periapalayam Check Dam area (Chennai). It is recommended that people using water from these wells should employ household-level low cost disinfection methods like boiling, chlorine tablets or chlorine solutions, solar disinfection, ceramic filters or bio-sand filters to ensure that the water is microbiologically safe to drink and meets the drinking water quality requirements.

6. References

Colwell, R.R., Huq, A., Sirajul Islam, M., Aziz, K. M. A., Yunus, M., Huda Khan, N., Mahmud, A., Bradley Sack, R., Nair, G. B., Chakraborty, J., Sack, D.A. and Russek-Cohen, E. (2003) Reduction of cholera in Bangladeshi villages by simple filtration. *Proceedings of National Academy of Science USA*, 100(3): 1051–1055.

Grimm, V. D. (2008). Wasserknappheit und Technologie. *VDI Technologiezentrum*.

IS 10500 (2012) *Indian Standard - Drinking Water Specifications (Second Revision), for drinking water*. Bureau of Indian Standards, New Delhi, India.

Sandhu, C, Grischek, T., Kumar, P. and Ray, C. (2011) Potential for Riverbank filtration in India. *Clean Techn Environ Policy*, 13: 295-316.

Lorenzen, G., C. Sprenger and Greskowiak, J. (2007): Results of background work and data integration of MAR systems for an Integrated Water Resources Management. - TECHNEAU. D 5.2.1. http://www.techneau.org/

Lorenzen, G., C. Sprenger and Pekdeger, A. (2010): Investigation of RBF potential in developing and newly industrializing countries: Lessons learnt from the Delhi case studies. - TECHNEAU. D 5.2.8. http://www.techneau.org/

Pekdeger, A., Lorenzen, G. and Sprenger, C. (2008): Preliminary report on data of all inorganic substances and physicochemical parameters listed in the Indian and German Drinking Water Standards from surface water and groundwater at the 3 (+1) field sites. - TECHNEAU. D 5.2.2. http://www.techneau.org/

Sprenger, C., G. Lorenzen, et al. (2008). Occurrence and fate of microbial pathogens and organic trace compounds at riverbank filtration sites in Delhi, India. TECHNEAU. D 2.5.6. http://www.techneau.org/

Sandhu, C. and Grischek, T. (2012) Riverbank filtration in India – using ecosystem services to safeguard human health. *Water Science & Technology: Water Supply*, 12(6): 783-790.

Saph Pani D1.1 (2012) Database of relevant pollutants in urban areas and their attenuation at RBF sites. EU Saph Pani Deliverable. www.saphpani.eu.

Saph Pani D1.2 (2013) Guidelines for flood-risk management of bank filtration schemes during monsoon in India. EU Saph Pani Project Deliverable D1.2. www.saphpani.eu.

Saph Pani D2.2 (2013) Documentation of acquired data and conceptual model of MAR impact as input for WP5 modelling. EU Saph Pani Project Deliverable D2.2. www.saphpani.eu.

Saph Pani D3.1 (2013) Report on experiences with constructed wetlands and techno-economic evaluation, EU Saph Pani Project Deliverable D3.1. www.saphpani.eu

Saph Pani D4.1 (2013) Review of the Post-treatment Applied to Natural Treatment Systems in India and Critical Water Quality Parameters. EU Saph Pani Project Deliverable. www.saphpani.eu.

Saph Pani D4.2 (2013) Removal Efficiency of Conventional Post-treatment after Natural Treatment Systems. EU Saph Pani Project Deliverable. www.saphpani.eu

Saph Pani D4.3 (2014) Post-treatment Requirements of Different Natural Treatment Systems. EU Saph Pani Project Deliverable. www.saphpani.eu

UJS (2012) Water Quality Data. Report on Saph Pani Project Baseline Survey of Water Supply Systems in Haridwar, Nainital and Sri Nagar. Uttarakhand Jal Sansthan, India.

WHO (2008) Guidelines for Drinking-water Quality. Third Edition Incorporating the First and Second Addenda. Volume 1 Recommendations. Geneva.

WHO (2011) Guidelines for Drinking-water Quality. Fourth Edition, World Health Organization, Geneva.

APPENDIX A

Typical Calculation for Estimation of Sodium Hypochlorite Dose in Haridwar

USE OF SODIUM HYPOCHLORITE AT TUBEWELLS WITH DILUTION IN DOSING TANKS

To Maintain 0.5 ppm at initial stage:- Requirement of NaOCl in Ml is calculated as per below formula.

Note:- Sodium hypo chlorite(grade II) having 12.5% concentration of Available chlorine i.e. 125 ml of active chlorine in one liter of sodium hypo chlorite

As per BIS to Maintain 0.5 PPM in one-lack liters of water 50 grams of active chlorine is required.

i.e. In 450 ml of Sodium hypo chlorite 59 grams of active chlorine is present(Due to transmission losses we consider 450 Ml per one lack liters instead of 400ml)

For different discharges of water supply, requirement of sodium hypo chlorite in ML is calculated from below formula.

Sodium hypochlorite (G-II) in ML (SHC)=(C or D of water) * 450/100000.

C=Capacity, D=Discharge, SHC=Sodium hypo chlorite

For example 1000 liters capacity /discharge of water,

SHC=1000*450/100000=4.5ML

FOR Different Discharges requirement of NaOCl mentioned below.

Sr. No.	Discharge of water/liters	Quantity of NaOCl
1.	5000	24 ML
2.	10000	45 ML
3.	20000	90 ML
4	30000	135ML
5	40000	180ML
6	50000	225ML
7	60000	270ML
8	70000	315ML
9	80000	360ML
10	90000	405ML
11	100000	450ML

TO Maintain 0.5 ppm at initial source take up the above quantity of Sodium hypo chlorite in ML for various discharges

SODIUM HYPOCHLORITE(SHC)IN DILUTION TANK WITH WATER IN LITERS

SHC in tank=(ML of SHC depending up on discharge capacity/No of liters injecting by dosing pump from diluted solution) * Tank capacity in liters/ 1000