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The performance of bank filtration for water supply in semi-arid climate: Case Study in BaniMurr, Assiut, Egypt

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ABSTRACT

Natural filtration is a process wherein surface water is filtered through the bank or bed of a river or lake. The process is referred as river/lake bank filtration (RBF/ LBF). Bank filtration has been shown to be effective in attenuating a wide variety of materials including turbidity, natural organic matter, pesticides, pharmaceuticals, taste and odor causing compounds and microorganisms etc. The RBF is considered as a classified and a low-cost treatment (or pretreatment) method.

This study presents an attempt to explore the potential implementation sites for the RBF technology in a full-scale RBF plant located in BaniMurr– Assiut - Upper Egypt as section of the Nile valley to produce drinking water.To predict the quality characteristics of the BF, water samples were collected from pumping wells placed near the potential BF site and the surface water system. There are 4 extraction wells in the BF field, which are operated mutually. Other set of water samples were collected from two test wells situated at the potential BF field at 7 m and 15 m away from the Nile River, respectively. These water samples were collected once a week for duration of three months

Quality measurements of physical, chemical, biological and microbiological characteristics were obtained. Comparison between the produced water with the surface and the natural background groundwater for the investigated plant has proven the effectiveness of RBF technique for potablewater supply in Upper Egypt under such hydrological and environmental conditions. However, there are some aspects that could restrict the BF efficacy and must therefore be considered during the design process. These include; i) over-pumping which increases the travel time and thus decrease the efficiency of treatment; ii) locating the wells near the surface water systems (<50 m) decreases the travel time to the limit (>10days) and thus could restrict the treatment capacity; iii) the consequences of lowering the surface water level can be regulated through the continuous operation of the wells.

It was concluded that longer travel increases the potential for environmental anaerobic conditions. This enhances the reduction of undesirable and toxic elements (e.g., Fe, Mn, and As), and consequently has an adverse effect on the bank-filtrate quality. Based on these assumptions, a travel time of 10 to 50 days was regarded as acceptable.The identification of the correct position to install the BF wells is a critical factor for the successful application of the BF technique.The economic study ultimately demonstrated that BF is an economic and sustainable technique for implementation in BaniMurr City to address the demand for potable water.

Keywords: Riverbank filtration, groundwater, economic feasibility, arid climate.

INTRODUCTION

Alluvial aquifers are widely used as a groundwater source in many countries, mainly due to their high production potential, proximity to demand areas, their ease, and economy of extraction. By pumping wells located in an alluvial plain hydraulically connected to a river, it is possible to generate a hydraulic gradient so that surface water is forced to flow through the bed and the banks of the river (UN Habitat for a better urban Future, 2018). During this process, known as riverbank filtration (RBF), a reduction of pollution levels is accomplished by a number of processes including physical filtration, microbial degradation, ion exchange, precipitation, sorption, and dilution. Other factors that also contribute to the treatment process include the river water and the groundwater quality, the porosity of the medium, the water residence time in the aquifer, temperature and pH conditions of water, and oxygen concentrations (Archwichai, 2011). Also, there are additional advantages of RBF. The first is relative to the fact that the flow through the aquifer acts as a barrier against concentration peaks that may result from accidental spills of pollutants. The second is the regulation on the temperature variations in the river water: during winter, when air temperatures are low, the filtered water is usually warmer than surface water, and in summer it is cooler. The lowest variation in temperature improves the quality and enhances further processing of the bank filtrate (Abdel Wahaab, 2019).

For RBF there are local factors such as river hydrology, hydrogeological site conditions (i.e., aquifer thickness and hydraulic conductivity), and the aims of water withdrawal that determine not only the capacity of the wells, but also the travel time of the bank filtrate, and distance between the river and the well (Grischek, 2003).

Riverbank filtration wells can be designed either vertically (as the most common practice especially for the extraction of low water quantities) or horizontally (for higher extraction rates). Horizontal wells (sometimes with a radial pattern), also known as collector wells, are usually directed toward the river and extract water from beneath the riverbed, whereas vertical wells extract water along the riverbed. Also, RBF wells can be distributed parallel to the riverbank in galleries or groups. The most important parameters for success during RBF are the flow path length, the thickness of the aquifer, and the infiltration area in the river (Marcela, 2012).

The main objective of this study is to analyze the performance of BF in BaniMurr–Assiut (Egypt) as an example of a semi-arid climate region and to use the results to suggest a guideline to facilitate the application of BF in Egypt as well as other countries with similar climatic and hydrological regime.The identification of the correct position to install the BF wells is considered a critical factor for the successful application of the BF technique (Abdel Wahaab, 2019). However, the major drawback of BF is that it is a site-specific technique, and therefore an extensive investigation must be conducted to determine the site’s viability for BF application.

MATERIALS AND METHODS

1. Location of the study area

BaniMurr is a city in the Asyut Governorate of Egypt. It is located on the east bank of the Nile at 27° 13′ 25″ N and 31° 11′ 35″ E (Fig 1).

Fig. 1. Location of the study site

The setting and design of an RBF system does not only depend on hydrogeological factors, but also on technical, economical, regulatory, and land-use factors.
This site was designed to supply potable water to the construction staff of residents. It consists of 4 productive groundwater wells (L1 , L2 , L3 , L4) ranging from 100 m to 150 m depth located at 100 m apart from the River Nile. There is Iron and manganese treatment unit and disinfection applying chlorine as calcium hypochlorite (Table 1).

Table 1. Details of productive groundwater wells in BaniMurr

Parameter	Unit	L1	L2	L3	L4
Start date	Year	2006	2019	2000	2015
Current status	-	on-duty	on-duty	on-duty	on-duty
Well diameter (inches)	Inches	10	12	10	12
Distance from river bank	m	65	90	30	35
Depth (m)	m	150	104.9	100	153
Solid pipes length (m)	m	65	63.8	65	84
Filter pipes length (m)	m	85	35.1	35	59
Pipes material	-	Metal	Plastic	Metal	Plastic

In the study area, two exploratory well was drilled in March 2020. The first northern test well (TW1) is located at 10 m from the riverbank and the second Southern test well (TW2) is located at a distance of 15 m from riverbank (Table 2).

Table 2. Design parameters of RBF wells.

Site	TW1	TW2
Depth of well (mbgs)	12	12
Location of filter screen	20- 25	15-20
Well diameter (inches)	14	14
Distance from river bank (m)	10	15
Pumping rate (L/s)	30	30
Static groundwater level (mbgl)	1.9	1.6

The submersible pumps were operated at a rate of about 30 L/s each. The static groundwater depth was 1.6 to 1.9mbgs (meter below ground surface) for TW1 and TW2, respectively. The two aquifers had a thickness of about 30 m. During drilling, soil profiles were taken and the results are summarized in Table (3).

Table 3. Thickness of the sediment layers with depth (mbgs) at the RBF sites

Site	TW 1	TW 2
Clay top	1-5	1–5
Fine sand	6-15	6-15
Medium sand	19-30	-----
Coarse sand	16-18	15-20
Gravel	32-38	20-30
Shale	----	----

2. Methods

The identification of the correct position to install the BF wells is a critical factor for the successful application of the BF technique (Abdel Wahaab, 2019). However, the major drawback of BF is that it is a site-specific technique, and therefore an extensive investigation must be conducted to determine the site's viability for BF application. Sandhu (2015) proposed a four-stage investigation plan for site selection; this plan can be described as follows:

(i) A preliminary evaluation of the potential sites by conducting field studies to collect information on the hydrogeological and hydrological properties of the water systems and collecting samples from the wells and surface systems.

(ii) an in-depth assessment of the potential sites to identify the appropriate locations for installing the BF wells, to determine the groundwater elevations at the investigated areas and to construct monitoring wells.

(iii) Determination of the hydrological parameters of the aquifer and monitoring of the surface water levels and quality.

(iv) Determination of the bank-filtrate proportion in the total water pumped.

3. The hydrological properties

To predict the water quality characteristics of the bank filtrate, water samples were collected from pumping wells placed near the potential BF site and the surface water system. There are 4 extraction wells in the BF field, which operated mutually. Second set of samples were collected from a test well (TW1 and TW2) situated at the potential BF field and from the Nile once a week for three months.

The aquifer is mainly recharged from the Nile River; therefore, samples were collected from the surface water systems (NR) to assess the efficiency of the BF process.

The physical parameters (temperature, TDS, pH, and turbidity) were determined on site using portable HACH, USA instruments. Chemical analysis including (Sulphate, Chloride, Total Alkalinity, Total Hardness, Ca Hardness, Mg hardness, Ca^{+2}, Mg^{+2}, Fe, NH_3, NO_2 and NO_3) were determined in at the laboratories of the Holding Company for water and wastewater (Assiut, Egypt).

Microbiological analysis includes (heterotrophic plate count (HPC), total coliform, fecal coliform, fecal streptococci, *Pseudomonas aeruginosa* and algae count) have been done for all samples.

The percentage of the infiltrated water from the surface water systems captured by the two BFwells was determined using chloride as a conservative chemical parameter based on the following equation (Hoehn, 2006; Maeng, 2010):

$$BF\% = CBF - CGW/ CSW - CGW * 100$$

Where, CBF, CSW, and CGW are the concentrations of the conservative parameter in the BF well, surfacewater, and native groundwater, respectively.

RESULTS AND DISCUSSION

Riverbed morphology and permeability

Riverbed profiles at BaniMurr show river geometry and riverbed bathymetry (Fig. 2). The average depths of the River Nile ranged from 1.4 to 5.4 m.The river depth was identified to be a critical parameter for RBF application along the river Nile. If the river depth is less than the thickness of the clay cap, RBF will not be feasible.The sediments along the western bank at BaniMurr were mainly fine sand with silt and black colour with clay layer 5 m in TW1 and 4.5 m in TW2.

The depth of River Nile at BaniMurr is about 5 m, with a maximum of 5.4m.

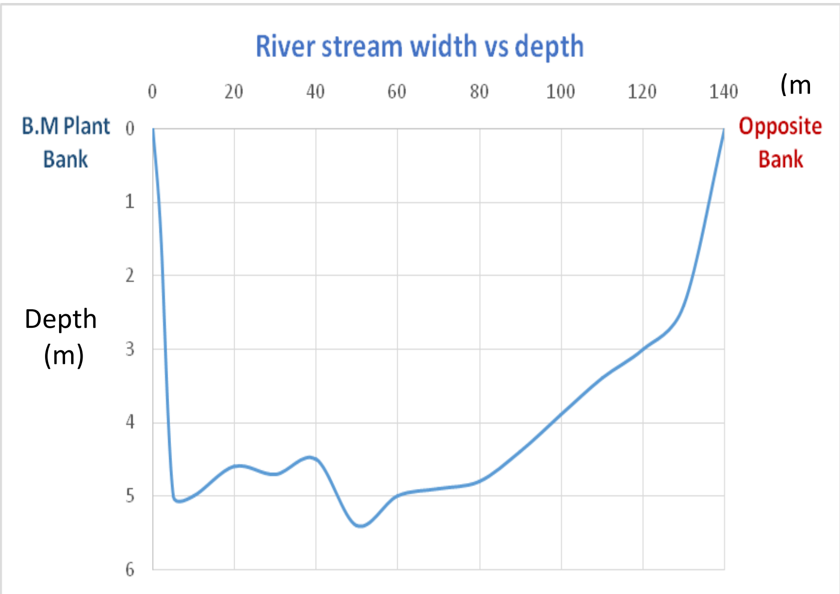

Fig. 2. Cross-section of the River Nile at the RBF site (prepared in May 2020).

Analysis of the borehole data in 10 m distance from the riverbank shows the possibility of presence of a transitional zone of silt and fine sand to 4.5 m underneaththe Nile riverbed at the intake side of the riverbank (Table 3).

A good hydraulic connection between the river and the aquifer is a prerequisite for the bank filtrate recovery. The Nile riverbed must cut into the aquifer or be lower than the bottom edge of the top layer. The average water depth of the river Nile varies from 1.4 to 5.4 m. The thickness of the clay layer in TW1 is too thick for the river to cut through and the shallow surficial sandy top layer has an insufficient thickness for the abstraction of water. These conditions prevent the hydrologic connection and thus are unfavorable for the riverbank filtration.

The Quality of River Nile and the Groundwater

The salinity of River Nile water is about 130 ppm; the chloride concentrations were 19 mg/L. All major ions in Nile water were generally within the limits for drinking water supply. The Nile water was alkaline and predominantly of the bicarbonate type. Total hardness is about 125 mg/L (as $CaCO_3$), with calcium as the main hardness constituent. The main problem in drinking water treatments is the high load of microbiological contaminants.The ambient groundwater, near the current the River Nile track, has TDS (Total dissolved Solids) ranging from 230 – 390 mg/L (Table 4). The TDS of the groundwater is more than the TDS of the river water. Additionally, chloride concentrations are also much higher.

In Egypt, risks might arise from the land-side part of the aquifer as it is subject to contamination, mainly from the unsecure conventional systems for sewage disposal in villages (latrines and septic tanks) but also from seepage of irrigation water containing nitrogen fertilizers (Grischek, 2003). However, median concentrations for ammonium and nitrate in the groundwater were found to be 0.6 mg/L and 0.8 mg/L, respectively, and did not indicate groundwater pollution. Maximum ammonium and nitrate concentrations found in the groundwater, at the studied sites, were 0.5 mg/L and 0.46 mg/L, respectively (Table 4). Besides primarily iron and manganese concentrations are relevant for water treatment design. Iron and manganese concentrations were found to be 0.1–0.3 mg/L for each (Table 4).

Bank-Filtrate Chemistry

At many RBF sites worldwide, seasonal temperature changes in river water and bank filtrates and flow-related changes in EC could be used to estimate the travel times of bank filtrate (Ahmed, 2020).The physical and chemical characteristics of the raw, infiltrated, and groundwater at the study area are summarized in Table (4b). It was expected that the banks acted as a robust barrier to the elimination of suspended matter but at the study location there is no significant difference in turbidity in comparison with the corresponding value at surface water systems (Nagy-Kovács, 2019).

However, the TDS values of groundwater, RBF wells and river water differ significantly, offering the potential to use TDS measurements to determine the portion of bank filtrates and land-side groundwater in the pumped water and residence times. Chloride concentration measurements might also be used. In any case, installation of an observation well, land-side of the pumping well is required.

The removal of organic compounds is relevant for the dissolution and release of iron and manganese along the flow path and for the required post-treatment and to inhibit the potential formation of disinfection by-products.

However, higher concentrations of nitrogen were found in the BF wells relative to the concentrations of the surface water bodies during this study. Its concentration increased to 0.6 mg/L at TW1 and 0.7 mg/L at TW2 (Table 4a). The principal reason for this increase is the mixing of infiltrated water with contaminated groundwater (Hamdan, 2011; Selim, 2014).

Chloride was used as conservative elements to estimate the percentage of infiltrated water from the surface water systems to the total pumped water at the two BF wells. The average chloride concentrations for the River Nile, TW1, TW2and GW were 19, 47.9,91.8 and 71.25 mg/L respectively. Therefore, the bank-filtrate share for TW1 was estimated to be 44.68 % where there is not any share for TW2.

The concentrations of major Cations (Ca^{+2}, and Mg^{+2}) and anions (Cl^{-1} and SO_4^{-2}) demonstrated increased behavior during the infiltration process. For example, the concentrations of Ca^{+2} and Mg^{+2} were 30.32 and 11.856 mg/L, respectively for the River Nile and increased to 117.29 and 32.04mg/L for the TWs (Table 4a). Similarly, an increase in the concentrations of heavy metals was detected at the BF wells. Fe and Mn were not detected in the surface water systems. This is mainly attributed to (i) dissolution of minerals during the filtration process and/or (ii) mixing of infiltrated water with the contaminated native groundwater (Abdelrady, 2020).

However, the concentrations of these elements in the pumped bank filtrates did not exceed thethreshold levels of drinking water quality guidelines proposed by WHO (2011) and therefore they do notpose a risk to human health. BF is recognized as an effective technique to reduce nutrient concentrations significantly (Maeng, 2019).

Table 4a. Chemical parameters of bank filtrates.

Sample location	Date	pH	Turb.	Sulphate	Chloride	TDS	Alkalinity	Hardness	Ca^{+2} ion	Mg^{+2} ion	Nitrite	Nitrate	NH_3	T. Fe	T. Mn
Parameter unit			N.T.U	mg/l											
Egyptian drinking water standards limitation		6.5 - 8.5	1	250	250	1000	--	500	140	36	0.2	45	0.5	0.3	0.4
Test well No. 1	21/06/2020	7.56	3.92	96	63	609.6	440	416	108	35.04	Nil	Nil	0.46	0.68	1.14
	27/06/2020	7.46	4.05	98.75	62	573	458.8	383.4	100.32	31.824	Nil	0.8	0.58	0.64	1.07
	01/07/2020	7.42	3.18	102.3	60	562	406	354.6	90.64	30.72	0.0007	Nil	1.74	0.64	0.78
	07/07/2020	7.42	3.57	84	54	450	420	316	80.8	27.36	Nil	Nil	0.38	0.66	1.07
	16/07/2020	7.32	3.11	52.6	45	453	370	263.6	58.56	28.128	Nil	Nil	0.62	0.59	1
	21/07/2020	7.4	3.89	66.98	40	390	351.4	271.4	60.96	28.56	Nil	0.8	0.45	0.61	1.11
	29/07/2020	7.11	2.14	65.2	45	382	358	270	68	24	Nil	Nil	0.58	0.56	0.63
	04/08/2020	7.86	2.44	78.93	41	381	306.2	282.4	70.96	25.2	Nil	0.3	0.4	0.47	0.65
	13/08/2020	7.23	3.2	83.14	45	427	342	320	78.4	29.76	Nil	0.2	0.52	0.8	0.88
	16/08/2020	7.34	1.65	75.72	42	369	392	280	78.4	20.16	0.001	0.2	0.49	0.48	0.77
	23/08/2020	7.29	2.59	70	35	316	314	294	74.4	25.92	0.001	Nil	0.3	0.48	0.76
	30/08/2020	7.42	2.25	83	43	325	306	274	74.4	21.12	Nil	0.9	0.52	0.5	0.64
Test well No. 2	21/06/2020	7.58	5.79	92.5	98	798	528	504	127.2	44.64	Nil	Nil	0.34	0.77	1.32
	27/06/2020	7.32	6.11	117.35	98	754	537	467.6	129.68	34.416	Nil	0.4	0.76	0.92	1.54
	01/07/2020	7.29	6.09	126.2	96	804	546.8	505.6	132.08	42.096	0.0003	Nil	1.27	0.87	1.2
	07/07/2020	7.28	5.4	109	90	684	588	438	120	33.12	0.001	Nil	0.6	0.9	1.69
	16/07/2020	7.21	5.2	95.9	90	725	520	455.2	110	43.248	0.001	0.1	0.65	0.8	2
	21/07/2020	7.34	5.72	95	85	609	507.8	330	99.12	19.728	0.005	0.4	0.71	0.81	1.6
	29/07/2020	7.11	6.11	110.6	84	610	488	424	120	29.76	0.016	Nil	0.51	0.8	1.21
	04/08/2020	7.58	6.24	146.13	113	767	612.4	567.4	184	25.77	0.038	0.4	0.7	0.88	1.5
	13/08/2020	7.06	6.11	130.6	95	670	472	460	141.6	25.44	0.02	0.1	0.55	0.77	1.23
	16/08/2020	7.3	5.21	111.8	93	602	396	460	138.4	27.36	0.037	1.6	0.55	0.67	1.12
	23/08/2020	7.25	3.89	102	85	501	476	440	136	24	0.032	0.1	0.32	0.77	1.24
	30/08/2020	7.38	3.93	105.2	75	471	422	392	108.8	28.8	0.007	Nil	0.46	0.61	1.03

Table 4(b). Cont.

Biological analysis for Bank-Filtrate:

Tables (5) indicated the results of the microbiological analysis includes (heterotrophic plate count (HPC), total coliform, fecal coliform, fecal streptococci, *Pseudomonas aeruginosa* and algae count in water samples from the investigated sites. It was obvious that water samples of test wells for RBF and ground water wells have normal range of viable bacterial count (HPC). However the total coliform, fecal coliform have been detected in a high density at raw water, it is not detected in test wells for RBF, ground water wells samples.This can be an indication for adequate travelling time between surface water and test wells to remove pathogens and provide high-quality drinking water. The total coliform counts in some wells exceeded the drinking water standards. The median value for total coliforms in the River Nile valley aquifer was 1600 CFU/100 ml.

Table 5(a). Microbiological parameters of bank filtrates.

Sample location	Date	T. Coliform	F. Coliform	F. Strepto	HPC	Pseudomonas	Algea Count
Parameter unit		cell/100ml					
Egyptian drinking water standards limitation		2	0	0	--	0	--
Test well No. 1	21/06/2020	0	0	0	--	0	8
	27/06/2020	0	0	0	--	0	--
	01/07/2020	0	0	0	--	0	4
	07/07/2020	0	0	0	10	0	--
	16/07/2020	0	0	0	5	0	10
	21/07/2020	0	0	0	10	0	12
	29/07/2020	0	0	0	10	0	--
	04/08/2020	0	0	0	--	0	2
	13/08/2020	0	0	0	5	0	--
	16/08/2020	0	0	0	10	1	36
	23/08/2020	0	0	0	10	1	8
	30/08/2020	0	0	0	30	1	--
Test well No. 2	21/06/2020	0	0	0		0	--
	27/06/2020	1	0	0		0	2
	01/07/2020	1.8	0	0		0	--
	07/07/2020	0	0	0	10	0	22
	16/07/2020	1.1	1.1	0	10	0	4
	21/07/2020	0	0	0	30	0	10
	29/07/2020	0	0	0	10	0	--
	04/08/2020	4	0	0		0	
	13/08/2020	0	0	0	260	0	70
	16/08/2020	0	0	0	10	1	34
	23/08/2020	0	0	0	15	1	10
	30/08/2020	0	0	0	50	1	10

Table 5(b). Microbiological parameters of surface waters and groundwater sources.

Sample location	Date	T. Coliform	F. Coliform	F. Strepto	HPC	pseudomonas	Algea count
Parameter unit		cell/100ml					
Egyptian drinking water standards limitation		2	0	0	50	0	--
Ground well No. 1	Aug. 2020	0	0	0	10	0	24
Ground well No. 2		0	0	0	10	0	12
Ground well No. 3		0	0	0	20	0	42
Ground well No. 4		0	0	0	10	0	0
Nile river (Raw water)		1600	490	--	--	--	2336

Quality of the Pumped Water from RBF Units

At many RBF sites worldwide, seasonal temperature changes in river water and bank filtrates and flow-related changes in EC could be used to estimate the travel times of bank filtrate (Zsuzsanna, 2019). Fluctuation, except in the maximum values during the low flow period of December and January, the water levels change, so the travel times are also affected by the changing gradients in the aquifer. However, the Chloride values of groundwater and river water differ significantly, offering the potential to use Chloride measurements to determine the portion of bank filtrates and land-side groundwater in the pumped water and residence times. Chloride concentration measurements might also be used (Trettin, 1999).

As shown in Equation (1), the percentage of the infiltrated water from the surface water systems captured by the two test wells was determined using chloride as a conservative chemical parameter.

Portion of bank filtrate in % = (CWt- CGW)/(CRiver -CGW) *100

Where, CWt is the chloride concentration in the test well water, CRiver is the chloride concentration in river water, and CGW is the chloride concentration in groundwater.

From Table (3), the portion of Bank filtrate in Test well No.1 is:

(48.42–71.25 / 19–71.25) *100 = 43.69 %

The portion of Bank filtrate in Test well No.2 is:

(91.83-71.25 / 19–71.25) *100 = No bank filtrate %

The Location of the test well (1) near the surface water systems decreases the travel time and increases the percentage of surface water.

Sustainability and Cost of RBF

RBF is a sustainable low-cost technology applicable in Egypt and could be integrated into the conventional Water treatment plant allocated on the Nile River banks as an additional source to secure water supply during accidental oil spills and extreme climate events. Many types of water treatment technology are used in Upper Egypt (Table 6), depending on criteria such as population number, water use (drinking or industries), and cost.

To cover a large population, e.g. >1 million consumers, water companies tend to establish large water treatment plants with capacities >17,000 m^3/day to 1 Mm^3/day or more. RBF units commonly consist of abstraction wells and a disinfection unit to provide safe drinking water (UN Habitat for a better urban Future, 2018). If Mn and/or Fe concentrations are above the threshold set by the drinking water standard, aeration and sand filtration must be added as treatment steps. Small conventional Water treatment plants (rapid sand filters) are plants similar to the large ones, with same treatment steps and chemicals but with a capacity less than 17,000 m^3/day. The small conventional Water treatment plants are used for remote areas with limited population or for industrial water supply. This type has some disadvantages, such as high initial cost, high running cost, and higher energy consumption.

Direct infiltration Water treatment plants (slow sand filters) use large sand and gravel filters to treat water withoutany coagulant dosage. Chlorine gas is used for disinfection in most cases. These Water treatment plant only produce small quantities of drinking water at a high operation cost.Treatment of water from groundwater wells commonly requires Fe and Mn removal and disinfection, as in many parts of Egypt, people must dispose sewage in the ground, resulting in groundwater quality deterioration. Fe and Mn removal is based on aeration or dosage of potassium permanganate and subsequent filtration, which affect the operation costs (Elsheikh, 2016).

Compact units (built-in units) produce up to 2,160 m^3/day/unit. These mobile units can be moved to any place and are typically installed on small canal banks to provide drinking water for smallcommunities. The basic process is sand filtration in small closed metal cylinders, each unit having three of them, and treatment processes are the same as in the conventional Water treatment plant (coagulation/flocculation) (Ulrika, 2011) .

Table (6) indicates low capital costs for RBF units (without Fe/Mn removal) and small conventional. WTPs. has the highest capital costs for (deep) groundwater wells and subsequent treatments are affected by the deep drilling of the wells and commonly require manganese removal. Additionally, the operational costs are lowest for the RBF units, as compared to the groundwater wells, due to a lower drawdown and associated lower energy demand. If Fe/Mn removal is required, the operational costs would be more similar to those of groundwater wells (Elsheikh, 2016) .

Table 6. Cost comparison between RBF units and other treatment techniques (UN Habitat for a better urban Future , 2018).

Capacity and Cost	RBF Unit	Small Conventional	Direct Infiltration	Groundwater Well	Compact Unit
Capacity (m3/day)	3000	8000	3000	2000	2000
Capital cost (Million EGP/Unit)	0.6	40	60	2- 10	15
Operational cost (Million EGP/Unit)	0.05	0.5	1.5	0.1	0.7

Proposed Site Selection Criteria

There are some aspects that could restrict the BF efficacy and must therefore be considered during the design process. These include the following:

Over-pumping practices can reduce travel time, and thus decrease the efficiency of treatment, Locating the wells near the surface water systems (<50 m) decreases the travel time to the limit (>10days), and thus could restrict the treatment capacity. In such case, a low pumping rate must be applied;

The consequences of lowering the surface water level can be regulated through the continuous operation of the wells (Ahmed, 2020).

Wintgens (2016) demonstrated that a subsurface travelling time of 50 days is adequate to remove pathogens and provide high-quality drinking water. Maeng (2019), conversely, found a negative relationship between the travel time and redox potential of the bank filtrate. This suggests that longer travel increases the potential for environmental anaerobic conditions. This enhances the reduction of undesirable and toxic elements (e.g., Fe, Mn, and As), and consequently has an adverse effect on the bank-filtrate quality. Based on these assumptions, a travel time of 10 to 50 days was regarded as acceptable.

Conclusions

RBF can serve as a pre-treatment for waterworks; at some sites only disinfection is required as a further treatment step for drinking water production. Results from water quality monitoring during the initial phase of the RBF operation in Upper Egypt have demonstrated a good surface and groundwater interaction, and favorable hydro-geological conditions. Data from all investigated sites showed an efficient removal of turbidity and bacteria during RBF.

Special care should be taken to prevent well contamination during the drilling and installation process. After initiation of pumping from the RBF wells, it might take 2 to 12 months until stable water quality is gained for the pumped water.

Decisions on adequate further treatment—especially if Fe/Mn removal is required should be made only after a monitoring period of a few months, to allow an optimal design for post-treatment. The RBF units should be operated continuously to prevent fluctuations in water quality and to limit the pumped portion of land-side groundwater, which commonly has higher Fe and Mn concentrations.RBF can provide large volumes of drinking water with a high quality at low cost. The capital and operating costs of the RBF units are lower, compared to conventional water treatment plants. The highlighted conditions and advantages of RBF in Upper Egypt underline that RBF should be considered as an option for water supply, without requiring any further treatment besides disinfection or as a pre-treatment step at some sites, especially if the capacity of the existing water treatment plants needs to be increased.

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أداء الترشيح الطبيعي للابار الشاطئية للموارد المائية في المناخ شبه الجاف: حالة دراسة في بني مر ، أسيوط ، مصر

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المستخلص

الترشيح الطبيعي هو عملية يتم فيها ترشيح المياه السطحية عبر ضفة أو قاع نهر أو بحيرة. يشار إلى العملية باسم ترشيح ضفة النهر / البحيرة (RBF / LBF) . لقد ثبت أن هذا الترشيح فعال في تخفيف مجموعة متنوعة من المواد بما في ذلك العكارة ، والمواد العضوية الطبيعية ، والمبيدات الحشرية ، والمستحضرات الصيدلانية ، والمركبات والكائنات الدقيقة التي تغير طعم ورائحة المياه وما إلى ذلك. تعتبر عملية الترشيح RBF طريقة معالجة منخفضة التكلفة.

تقدم هذه الدراسة محاولة لاستكشاف أفضل مواقع التنفيذ المحتملة لتقنية RBF في نطاق واسع يقع في بني مر - أسيوط - صعيد مصر كقسم من وادي النيل لإنتاج مياه الشرب. وقد تم جمع عينات المياه من آبار الضخ التواجدة بالقرب من موقع BF المحتمل ونظام المياه السطحية. هناك 4 آبار استخراج لعينات المياه في حقل BF ، يتم تشغيلها بشكل متبادل. كما تم جمع مجموعة أخرى من عينات المياه من بئرين اختباريين يقعان في حقل BF المحتمل على بعد 7 متر و 15 مترًا من نهر النيل ، على التوالي. تم جمع عينات المياه هذه مرة واحدة في الأسبوع لمدة ثلاثة أشهر.

تم أجراء قياسات الجودة للخصائص الفيزيائية والكيميائية والبيولوجية والميكروبيولوجية لعينات المياه . أثبتت المقارنة بين المياه المنتجة من المياه السحية والمياه الجوفية الطبيعية للمحطة التي تم فحصها فاعلية تقنية RBF لتزويد مياه الشرب في صعيد مصر في ظل الظروف الهيدرولوجية والبيئية بالمنطقة. ومع ذلك ، هناك بعض الجوانب التي يمكن أن تحد من فعالية BF وبالتالي يجب أخذها في الاعتبار أثناء عملية التصميم. وتشتمل على: i) الإفراط في الضخ والذى يزيد من وقت السفر وبالتالي يقلل من كفاءة المعالجة ؛ ii) تحديد موقع الآبار بالقرب من أنظمة المياه السطحية (<50 م) يقلل من وقت السفر إلى الحد الأقصى (< 10 أيام) وبالتالي يمكن أن يحد من قدرة المعالجة. ؛ iii) انخفاض مستوى المياه السطحية والذى يمكن التغلب عليه من خلال التشغيل المستمر للآبار.

استنتج من نتائج الدراسة أن السفر الأطول يزيد من احتمالية الظروف البيئية اللاهوائية. هذا يعزز تقليل العناصر غير المرغوب فيها والسامة (على سبيل المثال ، Fe ،Mn ، As)، وبالتالي يكون له تأثير سلبي على جودة عملية الترشيح . بناءً على هذه الافتراضات ، تم اعتبار وقت السفر من 10 إلى 50 يومًا مقبولاً ، ويعتبر تحديد الموضع الصحيح لتركيب آبار BF عاملاً حاسمًا للتطبيق الناجح لتقنية BF . أظهرت الدراسة الاقتصادية في النهاية أن BF هو تقنية اقتصادية ومستدامة للتنفيذ في مدينة بني مر لتلبية الطلب على مياه الشرب.