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Research article

Biodegradation Model of Dissolved Organic Matter during River Bank Filtration, Al Qurin, Sharkyia, Egypt

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ABSTRACT

Riverbank filtration carry out with natural conditions and also may be occur by lowering of the ground water stream under the surface water levels either by hydraulic boundaries such as bank of channels, or by groundwater abstraction at pumping wells. In addition, the mixing of the infiltrated river water with groundwater at the pumping outlet well, the retention time of the bank filtrate has been studied and identified as one of the key parameters that determinate the efficiency of riverbank filtration and water quality. Previous studies have reported that the level of organic matter and other contaminants reduced with high pass through time. RBF water results of pH, conductivity, TDS, hardness, color, alkalinity, nitrate, nitrite, phosphate, silica, sulphate, chloride, and turbidity were complying with the Egypt and WHO guidelines. The present study showed that, the data of iron and manganese of ground water in the study region, didn`t comply with Egyptian regulation (Fe more than 0.3 mg/l and Mn more than 0.4 mg/l). The results of river surface water quality didn't comply with Egyptian regulation in some parameters such as, microbiological parameters (total bacterial count more than 5000 CFU/ml) and also the examination of river surface water samples were positive in total coliform and fecal coliform examination. The study has showed that, the water quality results from the RBF water had high water quality especially in values of Fe & Mn and also microbiological parameters. The correlation coefficient between DOC recorded and DOC estimated was very strong (r was 0.94).

Keywords: River bank filtration water quality; Dynamic model; Al Qoran, Sharkyia; Egypt

INTRODUCTION

Riverbank filtration (RBF) production an inexpensive, sustainable and effective techniques for water treatment and also improve the quality of surface water (Brunke). In RBF process the surface water is passes through the river-bank and the aquifer, the infiltrated water is exposed to some processes such as sorption, physicochemical treatment and biodegradation. The processes of sorption, biodegradation and physicochemical filtration are efficient in removing of suspended solids, viruses, bacteria, parasites, some pollutants, and organic and inorganic compounds that may be present in surface waters, like natural organic matter and ammonium (Brunner) [1].

The riverbank filtration process is effectively in water treatment and has been recognized in Europe, where many countries were uses the RBF in their drinking water demand (˜54% in France and Slovak Republic, ˜46% in Finland, ˜44% in Hungary, ˜27% in Switzerland and ˜17% in Germany (Cirpka). Hence, RBF supply a drinking water resource, which needs to be protected and maintained, especially within the context of some challenges like river restoration and climate change [2].

Therefore, the management of RBF systems in a varying environment needs a good understanding of the biogeochemical and physical processes that occur during RBF system (Derx) [3].

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RBF can proceed with natural conditions and or can be induced by a groundwater aquifer under surface water levels either by hydraulic boundaries like side

channels, and or by groundwater pumping (Figure 1). When the groundwater level is exceeds by a few decimeters below the river-bank, the hydraulic connection is lost and river water infiltrates through an unsaturated zone, which is aerated (Froyland;Doetsch).

RBF systems are typically positioned in alluvial valley aquifers, which predominantly consist of gravels and sands allowing for high abstraction rates [4].

The elimination of pathogenic microorganisms was found to be affectively and related to the traveling time. A breakthrough of E. Coli at a pumping well site at the Rhine River was determined after a flood occur, because of shortened groundwater travelling times (Huggenberger). Therefore, to be ensuring that the water production is high quality and safe, few travelling times are often required by local regulation and law and the protection zones should be identified (IPCC). The required groundwater residence time between the river and a pumping well is between 10 and 14 days in Switzerland (Pasquale) and between 50 and 60 days in Germany (Peter). Infiltration Water River is subject to a geochemical water properties changes that are related to redox reactions, dissolution/precipitation of minerals, ion exchange and gas exchange (Puschetal; Reichert). Several studies have illustrated that the most significant geochemical changes were associated with the biodegradation of natural organic matter. The degradation process was found to proceed dominantly in the first few meters of infiltration, where the microbial abundance and activity was highest. This interface between the river and alluvial groundwater, the hyporheic zone, has been identified as a distinct environment playing a crucial functional role in the biogeochemical cycling of nutrients and organic matte r(Sacher). NOM in river systems originates from both allochthonous (terrestrially-derived) sources and generally more biodegradable autochthonous sources (periphyton) (Reichert). NOM is composed of dissolved organic matter (DOM) and particulate organic matter (POM). During infiltration of river water, DOM is transported through the riverbed as a "mobile substrate", whereas POM is retained in the riverbed sediments as a "stationary substrate" (Pusch). The retention and storage of POM within the riverbed was found to depend on the grain-size distribution of the riverbed sediments and the hydrologic conditions (Brunke and Gonser).The microbially NOM degradation was mediated and depends on environment temperature (Brunke and Gonser). Redox conditions at different RBF systems were shown to undergo seasonal variations with the present of anoxic conditions in hot season (Peter). Besides temperature, the redox conditions in the infiltration zone are also affective by the availability of electron donors (NOM, ammonium) and electron acceptors (dissolved oxygen, nitrate). During industrialization in the 1950s and 1960s, the rivers in urban areas carried high loads of organic materials and ammonium (Horner). The combination with low oxygen levels in river water, strongly reducing conditions prevailed in the infiltration zones of several RBF systems that cause the mobilization of Mn and Fe. Since the 1970s, river water quality has improved significantly and oxic conditions in infiltration zones re-established (Horner) [5].

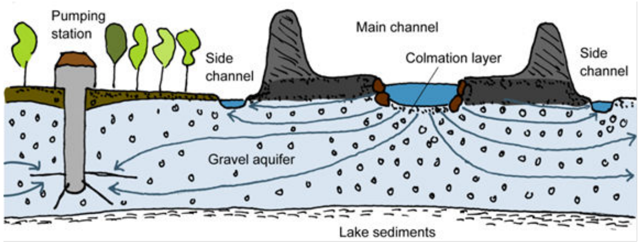

Figure 1: River bank filtration diagram

The study aimed to evaluate the river bank filtration water quality and try to modeling the organic matter biodegrading during passing through the river bed.

METHODOLOGY

Sampling

The water samples collected from the Al Qurin water treatment plant, Sharkyia governorate during the period of study. The collected samples were submitted to the Reference laboratory, for subsequent analysis (physical, chemical, biological and microbiological analysis) (APHA) [6].

Material

All material, reagents and standards used in the present study are high quality and American Chemical Society (ACS) vendors which used in analytical laboratories.

Analytical Methods

Water samples collected from the Al Qurin water treatment plant, Sharkyia governorate during the period of study. The collected water samples were refrigerated at 4oC for subsequence laboratory tests. The collected samples were submitted to the laboratory, for subsequent analysis (physical, chemical, biological and microbiological analysis) according to the reference methods in the Standard Methods for Water & Wastewater Examination (APHA). SPSS 21 software was used for data analysis of dissolved organic matter investigation and biodegradation studies through river bank filtration [7].

RESULTS AND DISCUSSION

The study aimed to simulate the dynamics of dissolved organic matter and abstracted water flow (m3/hr) consumption during riverbank filtration across a building dynamic model as shown in Table 1 and Figure 2. The values of DOC in surface, ground and RBF were measured and recorded and also the measurements of water flow of RBF was recorded and water flow of ground and surface were estimated. The verification of the model was calculated and recorded (Eq. 1) as shown in Table 1 and Figure 2 [8-10].

The model implementation is fast and simple and model run times are short compared to spatially explicit numerical reactive transport models. Hence, the modeling approach provides an efficient tool to estimate TOC concentrations in groundwater from those measured in the river under various climatic and hydrologic conditions [11-16].

The correlation coefficient between DOC recorded and DOC estimated was very strong (0.94), as shown in Table 1.

The study aimed to evaluate the water quality that collected from surface water, conventional underground water and RBF water, Al Qurin, Sharqyia, Egypt. The results of water pH, conductivity, TDS, hardness, colour, alkalinity, Nitrate, nitrite, phosphate, silica, sulphate, chloride, and turbidity were illustrated in Table 2. TDS and water turbidity were shown in Figures 4 and 5.

The results of pH, conductivity, TDS, hardness, colour, alkalinity, nitrate, nitrite, phosphate, silica, sulphate, chloride, and turbidity were complying with the Egypt and WHO guidelines (WHO, 2011). While the results of iron and manganese of ground water didn`t comply with Egyptian regulation (Fe more than 0.3 mg/l and Mn more than 0.4 mg/l), as indicated in Table 2 and Figures 7 and 8.

The results of surface water quality didn't comply with Egyptian regulation in microbiological parameters (total bacterial count more than 5000 CFU/ml) and also the examination of surface water samples were positive in total coliform and fecal coliform examination, as indicated in Table 2 and Figure 6.

Table (1): Dissolved organic matter prediction through river filtration

	DOC0 (mg/l)	DOCg (mg/l)	Qi (m3/hr)	Qg (m3/hr)	Qr (m3/hr)	a	b	DOCr (mg/l)	DOCactual (mg/l)
1	5.5	0.3	86	16	102	0.26	0.13	1.21	1.36
2	4.8	0.2	81	22	103	0.26	0.13	0.99	1.1
3	3.9	0.22	77	31	108	0.26	0.13	0.73	0.96
4	2.8	0.12	69	43	112	0.26	0.13	0.45	0.58
5	3.8	0.19	82	20	102	0.26	0.13	0.80	0.98
6	3.6	0.13	81	23	104	0.26	0.13	0.73	0.88
7	4.4	0.16	86	29	115	0.26	0.13	0.86	0.94
8	4.9	0.15	91	12	103	0.26	0.13	1.13	1.28
9	5.8	0.14	74	28	102	0.26	0.13	1.10	1.16
10	5.4	0.1	76	25	101	0.26	0.13	1.06	1.18
11	5.7	0.1	75	24	99	0.26	0.13	1.13	1.19
12	6.5	0.12	72	32	104	0.26	0.13	1.17	1.22
13	6	0.15	77	28	105	0.26	0.13	1.15	1.26
14	6.1	0.16	74	36	110	0.26	0.13	1.07	1.17
15	6.2	0.19	73	35	108	0.26	0.13	1.10	1.2
16	3.6	0.1	72	30	102	0.26	0.13	0.66	0.75
17	3.9	0.12	72	34	106	0.26	0.13	0.69	0.77
18	3.3	0.1	73	31	104	0.26	0.13	0.61	0.8
19	3.4	0.1	77	29	106	0.26	0.13	0.65	0.8
20	4.8	0.16	79	25	104	0.26	0.13	0.95	0.99
21	4.5	0.15	82	20	102	0.26	0.13	0.94	1.1
22	4.2	0.14	83	18	101	0.26	0.13	0.90	1.1
23	4.1	0.13	84	19	103	0.26	0.13	0.87	1.02
24	4.6	0.13	79	29	108	0.26	0.13	0.88	1.1
25	4.2	0.12	77	31	108	0.26	0.13	0.78	0.95
26	5.3	0.17	74	30	104	0.26	0.13	0.99	0.99
27	5.2	0.18	73	33	106	0.26	0.13	0.94	1.21
28	5.7	0.19	72	35	107	0.26	0.13	1.01	1.2
29	5.5	0.18	74	28	102	0.26	0.13	1.04	1.14
30	5.3	0.17	75	28	103	0.26	0.13	1.01	1.12
31	5.2	0.16	79	26	105	0.26	0.13	1.02	1.14
32	5.4	0.18	82	20	102	0.26	0.13	1.13	1.19
33	4.9	0.15	80	26	105	0.26	0.13	0.98	1.1
34	4.7	0.14	77	23	100	0.26	0.13	0.95	1.06
35	4.4	0.12	75	26	101	0.26	0.13	0.85	0.97
36	3.5	0.1	72	30	102	0.26	0.13	0.65	0.8
Correlation Factor (r) = 0.94									

DOC0: Dissolved organic matter concentration in the canal (mg/l)

DOCg: Dissolved organic matter concentration in the ground water (mg/l)

DOCi: Dissolved organic matter concentration in the RBF water (mg/l)

DOCr: Predicted (Calculated) Dissolved organic matter concentration in the RBF water (mg/l)

Qi: the water flow rate (m3/Hr) of RBF well

Qr: the water flow rate (m3/Hr) from main stream (canal)

Qg: the water flow rate (m3/Hr) from ground water (surrounded area)

a, b and c constant

Empirical Model: DOCr (mg/l) = (a x (DOC0 x Qi) + b x (Qg x DOCg))/(Qr) Eq. (1)

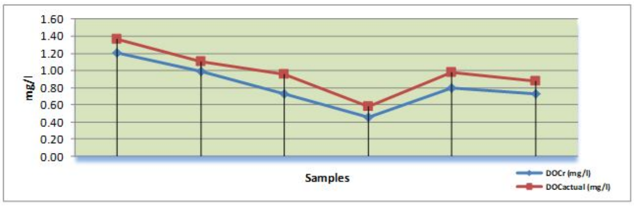

Figure 2: Dissolved organic matter prediction through river filtration

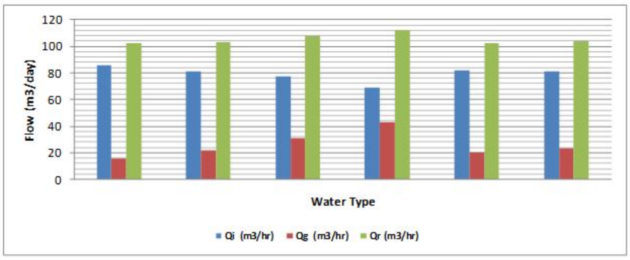

Figure 3: Water flow and water type

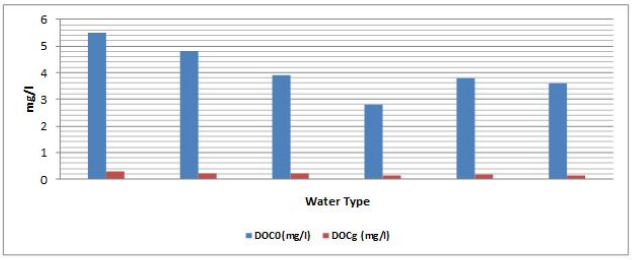

Figure 4: Dissolved organic matter and water type

Turbidity Removal

Table (2) shows monthly turbidity results of El saadia canal and water from (El mezainin RBF, ground water well 2). El saadia canal turbidity varied during this period from 8.4 to 19.2 NTU. The turbidity of El mezainin RBF and ground water well 2 remained stable and were consistently below 0.39 NTU. The results of El mezainin RBF and ground water well 2 are ranged during the same period from 0.08 to 0.27 NTU and 0.13 to 0.39 NTU, respectively. The data shows that the reduction of turbidity with El mezainin RBF and ground water well 2 was about 98 %. Juttner, 1995; Kühn and Müller, 2000, are cited that; the highest reduction percentage of turbidity in the RBF system, also the studies of Wang, 2002; Stefan Stauder et al., 2012 were showed that, the highest performance and stability of RBF system in reducing turbidity.

Total dissolved salts, Iron and Manganese

The total dissolved salts result of the El saadia canal varied from 192 to 228 mg/l, El mezainin RBF from 259 to 295 mg/l and ground water well 2 from 413 to 444 mg/l during the study period as shown in Table 2 . Many studies were conducted by Shamrukh and Abdel-Wahab, 2008; Schijven et al., 2002; Donald and Grygaski, 2002, showed that, the TDS was significantly reduced in RBF system than ground water to be under the allowable limits for potable water.

Table 2 illustrated the iron and manganese results of El saadia canal, El mezainin RBF and ground water well 2. Fe concentration in El saadia canal ≤ 0.016 mg/l and Mn concentration ≤ 0.007 mg/l, El mezainin RBF results of Fe varied from 0.007 to 0.02 mg/l and Mn varied from 0.001 to 0.009 mg/l, ground water well 2 results of Fe varied from 0.26 to 0.49 mg/l with average 0.39 mg/l and Mn varied from 0.06 to 0.14 mg/l. Many studies were conducted by Shamrukh and Abdel-Wahab, 2008; Wang, 2002; Stefan Stauder et al., 2012, showed that, the values of Fe and Mn concentrations in RBF system are less than ground water.

Table 2: The water-quality monitoring analysis for El saadia canal, El mezainin RBF, ground water well 2 and EL Qurin water Planet during period study

Sample type	Unit	El Saadia canal (Surface water)	Ground water well 2	El mezainin RBF
Parameter		**Range (MIN-MAX)**		
Temp.	0C	16.6-21.5	17.5-23	17.1-22.3
pH	-	7.95-8.2	7.48-7.9	7.79-8.1
Conductivity	uS/cm	320-380	688-740	432-552
Turbidity	NTU	8.4-19.2	0.13-0.39	0.08-0.27
Alkalinity	mg/l	113-139	212-240	140-156
TDS	mg/l	192-228	413-444	259-295
Total Hardness	mg/l	121-162	224-264	152-173
Sulphate	mg/l	36-46	180-186	40-44
Chloride	mg/l	20-39	45-55	22-28
Nitrate	mg/l	0.71-1.3	0.69-0.9	0.05-0.2
Nitrite	mg/l	0.05-0.16	0.01-0.02	0.01-0.02
Silica	mg/l	1.8-2.7	0.5-1	0.5-0.8
Iron	mg/l	0.01-0.016	0.26-0.49	0.007-0.02
Manganese	mg/l	0.001-0.007	0.06-0.14	0.001-0.009

Microbiological stability

The results of surface water quality in microbiological parameters (total bacterial count more than 5000 CFU/ml) and also the examination of surface water samples were positive in total coliform and fecal coliform examination.

The important aspect of El mezainin RBF performance is the microbiological water quality, as indicated in Table (3) and Figure (4).

Some previous studied that executed by Brauch and Kuhn, 1986, Schubert, 2002; and Weiss et al., 2002, the studies illustrated that, a many of substances existing in surface water including particles, bacteria, algae, viruses, parasites and micro pollutants are largely and in most situations perfectly reduced by RBF.

Sample type / Parameter	Unit	Raw surface water	Ground water	RBF water
Total algal count	U/ml	112000	12	5
Total bacterial count	CFU/ml	43000	32	4
Total coliform	CFU/100ml	411	Nil	Nil
Fecal coliform	CFU/100ml	156	Nil	Nil

Table 3: Average water quality parameters at period of El saadia canal, El mezainin RBF and ground water well 2

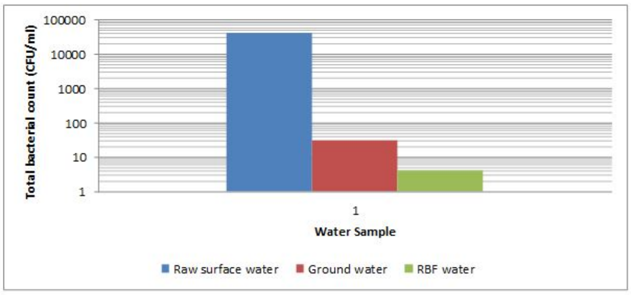

Figure 4: Total bacterial count (CFU/ml) of raw surface, ground and RBF waters

CONCLUSION

- The present study concluded that the collected water from ground water at Al Qurin city didn`t comply with the local regulation and exceeds of WHO guidelines (Fe &Mn).
- The present study concluded that the collected water from surface water at Al Qurin city didn`t comply with the local regulation and exceeds of WHO guidelines (total bacterial count and fecal coliform).
- The collected water samples from surface water may be contaminated may be due to discharge of improperly wastewater treatment to the main stream (fresh water), so it may be unsafe for human consumption.
- The study has presented a new semi-analytical model to simulate the dynamics of dissolved organic matter and abstracted water flow (m3/hr) consumption during riverbank filtration. The model implementation is fast and simple and model run times are short compared to spatially explicit numerical reactive transport models. Hence, the modeling approach provides an efficient tool to estimate TOC concentrations in groundwater from those measured in the river under various climatic and hydrologic conditions.
- The study results showed that as the water abstraction from RBF higher that the quantity abstracted from ground water, the RBF water production had high water quality especially in values of Fe &Mn and also microbiological parameters.
- The correlation coefficient between DOC recorded and DOC estimated was very strong (0.94).

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