Assessment of River Bank filtration for the removal of some chemical pollutants under different climate and environmental conditions

Thesis

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ABSTRACT

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Title of thesis: Assessment of River Bank filtration for the removal of some chemical pollutants under different climate and environmental conditions

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Bank filtration (BF) is a cost-effective technique that has been used widely in many developed countries for providing drinking water with high quality. Recently, this technique is applied in developing countries (e.g., Egypt) under different environmental and climatic conditions. The main objective of this research is to assess the capabilities of BF to remove specific pollutants under Egyptian conditions. The field study has been conducted in Upper Egypt, (El-Minya) along the River Nile and its distributaries. The investigations have included drilling test boreholes, recognition of both the subsurface profile and hydraulic parameters of the productive layer. Moreover, continuous monitoring of water quality has been done during the period of Jan. 2016 to Dec. 2016 on a monthly basis. Water samples were collected from both the surface water and bank filtration wells, the samples were analyzed and the chemical pollutants (e.g., pesticides, pharmaceuticals, inorganic) were determined. The Nile valley aquifer has the high potentiality to produce a high quantity of subsurface water. The thickness is more than 40 meters and means hydraulic conductivity is 0.0006 m/s. Nevertheless, the hydraulic connection is not clearly recognized and if the River Nile and its distributaries are fully or partly cutting the top layer (silt and clay). This has entailed using major tracers as EC and Chlorides. The bank filtration share ranges from 60 to 90%. The chemical analyses results refer to the high capability of this technique to remove organic pollutants, the DOC removal was ranged between 62 and 81%. The high removal of organic matter during the filtration process is mainly attributed to the high concentration of labile matter in the raw water that efficiently removed by biodegradation. The concentration of some parameter was decreased by more than 90% during the BF process such as (turbidity, TDS, pathogens, protozoa, iron, manganese, etc). These results refer that there is potentiality to apply BF under the Egyptian environmental conditions. BF

techniques deserve detail investigation under the Egyptian conditions in order to support the current conventional techniques infeasible localities along the River Nile and its distributaries in Egypt. Laboratory studies such as batch and column were conducted to get insight on the mechanical removal of the organic contaminants and to assess the impact of temperature (15, 25, 30 ºC) and redox condition (oxic, anoxic) conditions on the removal. The results revealed that bank filtration can remove the inorganic pollutants such as nitrate and nitrite efficiently. However, its effectiveness to remove organic pollutants is highly dependent on the temperature; higher removal was obtained at a higher temperature. To conclude, bank filtration is an effective technique to remove chemical contaminants and to produce high water quality, and it is highly recommended to extend the usage of this technique in Egypt.

Keywords: bank filtration, Egypt, organic and inorganic pollutants.

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SUMMARY

This work has focused on the investigation of the potentiality of riverbank filtration technique to produce drinking water under arid conditions. It has based on running both field site investigations and lab experiments (column & batch). selected one field site that has >90% bank filtrate. The field site investigations included measuring the physical, inorganic and organic constituents in both the River Nile water and bank filtrate water. The following is a summery for results from the field site for both the River Nile and the well field bank filtrate:

1. **The physical parameters**

- **Temperature (C°)**

The results showed that a decreased in water temperature by 5-7ºC during the filtration process. The water temperature was reduced from 27.5 to 21 ºC approximately in summer and from 12 to 9.4 ºC in winter at

- **pH** has been increased slightly from 8 to 8.2
- **DO (mg/L)**

the dissolved oxygen was decreased by 2 mg/L during the passage of the water into the pumped wells

- **The total dissolved solids**

showed an increasing trend during the filtration process. The average level of total dissolved solids was increased from 210 mg/L to 290 mg/L increase in the total dissolved solids was recorded. The main reason for this is attributed to the dissolution of metals and ions and its migration to the infiltrate water

- **Conductivity**

increasing in wells by 10–38 %

- **The turbidity**

was reduced from an average of 8.3 NTU to 0.25 NTU the high removal of turbidity during the filtration process indicates that bank filtration is a viable technique to remove suspended solids and enhance the biological stability of the water.

2. **The inorganic constituents.**

- **COD, BOD, TSS, phosphate, oil& grease, fluoride**.

The decreasing trend was appeared in the beginning of the infiltration process due to the high ability of filtration area to remove the organic pollutants through adsorption and biodegradation process

- **Nitrate, Nitrite, Ammonium.**

Nitrate concentration in the river water was found to be very low; probably there is already strong denitrification in the river itself due to its high temperature. The decrease in nitrate does not explain the increase in ammonium, which is relatively, slightly high with a minimum of 0.02 mg/l in bank filtrate. A maximum value of 0.55mg/l is high and a challenge for appropriate water treatment. The biologic decomposition is probably a more common cause for high ammonium than denitrification

- **Hardness, calcium, magnesium, sodium.**

increased due to the degradation of organic matter in the riverbed and/or aquifer

- **Alkalinity.**

increased slightly due to the degradation (bicarbonate concentration) in aquifer

3. **Trace metals**

- **nickel, zinc, selenium, lead, boron and barium, cadmium, chromium and arsenic.**

The results showed that <LOQ in wells due to the results showed in Nile river <LOQ

- **Manganese and Iron.**

In this research, an increase in both manganese and iron values has been observed during the filtration process. The average values of both iron and manganese have slightly increased than the Egyptian drinking water standards values; 0.3 and 0.4 mg/l respectively.

4. **Chlorinated Pesticides, Polyaromatic hydrocarbons, and Pharmaceutical residues.**

The results showed that <LOQ in wells due to the results showed in Nile river <LOQ

5. **Organic matter.**

It can be shown that the total organic carbon (TOC) removal has reached about 36 %, the TOC average values in bank filtrate wells were 1.3 mg/l and 1.9 mg/l.

Laboratory Studies (Column & Batch experiments)

The impact of discharge, retention time and soil characteristics on the removal efficiency of specific contaminants in water has been investigated in detail. The summery for these simulations is as follow:

6. **Discharge (flow rate) and Retention Time.**

- **Colum laboratory-scale**

The flow rate and retention time effect on RBF removal efficiency. the observation showed that when the flow rate is increased, the removal percentages of TOC is also increasing as well as the retention time.

7. **Soil Characteristics**

- **Colum laboratory-scale**

the observation showed that; as the soil composition variation, the flow rate increased, and the removal percentages of TOC increases, in Column (1), the soil component (Sand 50%, Clay 46% and Gravel 4%), the TOC removal was 80.0% while the TOC decreased from 77.1 to 76.7 % in Columns 2 and 3 with soil component (Col. 2: Sand 65%, Clay 30% and Gravel 5% and Col. 3:Sand 75%, Clay 22% and Gravel 3%)), respectively.

8.Effect of environmental conditions on carbamate compounds removal

- **Batch laboratory-scale**

•Adsorption is the primary mechanism to remove these pollutants during the bank filtration process.

•Increasing the clay contents in the filtration media leads to increase the removal efficiency as the biological activity related to the soil increased and so the biodegradation rate is higher

•Oxic condition is the favorable conditions to remove organic pesticides compounds during the filtration process

•The temperature has an influential role in the removal of Carbamate with favorable removal at low temperature

•15 °C is the preferred temperature to remove these pollutants during the bank filtration process

•Adsorption plays the primary role in the removal of hydrophobic compounds with low solubility characters. However, biodegradation is the dominated mechanism in the removal of hydrophilic compounds with high solubility and contain amino groups**.**

9. Effect of environmental conditions on polyaromatic compounds removal

- **Batch laboratory-scale**

•Compounds with higher solubility had lower removal efficiency

•Increasing the number of rings of PAHs will decrease its solubility and increase its removal efficiency

•The temperature has a real effect on the removal of PAHs, and it is in a positive relationship with PAHs removals

•15 °C is the preferred temperature to remove these pollutants during the bank filtration process

•Redox conditions don't play a vital role in the removal of PAHs

•Adsorption is the primary mechanism to remove these pollutants during the bank filtration process

10.Effect of environmental conditions on pesticides compounds removal.

- **Batch laboratory-scale**

•Compounds with higher solubility had lower removal efficiency

•Increasing the number of rings of Pesticides will decrease its solubility and increase its removal efficiency

•The temperature has a real effect on the removal of Pesticides, and it is in a positive relationship with Pesticides removals

•30 °C is the preferred temperature to remove these pollutants during the bank filtration process

•Redox conditions don't play a vital role in the removal of Pesticides

•Adsorption is the primary mechanism to remove these pollutants during the bank filtration process

No.	Abbreviations	Meaning
1	APHA	American Public Health Association
2	ASTM	American Society of Testing Material
3	ATP	Adenosine Triphosphate
4	BF	Bromoform
5	BOM	Biodegradable Organic Matters
6	CF	Chloroform
7	COD	Chemical Oxygen Demand
8	CSWT	Conventional Surface Water Treatment
9	DBCM	Dibromochloromethane
10	DBPs	Disinfection By-Products
11	DCBM	Dichlorobromomethane
12	DCE	Dichloroethanes Organic matters
13	DDD	DicholorDiphenylDicholorethyane
14	DDE	DicholorDiphenylDicholorethyene
15	DDT	DicholorDiphenylTricholorethyane
16	DNRA	Dissimilatory Nitrate Reduction to Ammonium
17	DOC	Dissolved Organic Carbon
18	EC	Electric Conductivity
19	EEA	Egyptian Environmental Agency
20	EfOM	Effluent Organic Matter
21	EPA	American Environmental Agency
22	ETC	Electron Trapping Capacity
23	FAO	Food and Agriculture Organization of
24	FEEM	Fluorescence Excitation - Emission Matrix
25	FEFLOW	Finite Element subsurface of Flow
26	FLD	Fluorescence Detector
27	FNU	Formazan Nephelometric Unit
28	GIZ	German Agency for International Development
29	HCWW	Egyptian Holding Company for Water
30	HPC	Heterotrophic plate counts
31	m.a.s. l	Meters above mean sea level
32	mbgs	meters below ground surface
33	NASRI	Natural and Artificial System for Recharge and Infiltration

No.	Abbreviations	Meaning
34	NOM	Natural Organic Matter
35	NTU	Nephelometric Turbidity Unit
36	OMPs	Organic micropolutins
37	PAHs	Polyaromatic compounds
38	PCA	Principal Components Analysis
39	PCs	Principal Components
40	PhACs	Pharmaceutically Active Compounds
41	PVC	Poly vinyl chloride
42	RBF	River Bank Filtration
43	REGWA	Groundwater Research Company (Egypt)
44	RNA	Ribonucleic acid
45	SUVA	Specific UV Absorbance the United Nations
46	TDS	Total Dissolved Solids
47	THMs	Trihalomethanes
48	TOC	Total Organic Carbon
49	TSS	Total Suspended Solids
50	UVA	UV – Absorption
51	WHO	World Health Organization