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karim b h, hussein s elsharkawy

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Hydrological Study of Groundwater and its Appropriateness for Irrigation

Karim Badr Hussein[1] and Hussein S. El-Sharkawy[2]
1 Lecturer of Irrigation and Hydraulics, Faculty of Engineering, Al-Azhar University
2 Lecturer of Sanitary and Environmental Engineering, Faculty of Engineering, Helwan University

Abstract- **Irrigation in most countries represents the largest share of water use. Groundwater is the main source of water after the Nile River in Egypt. The water situation in the future is not optimistic due to the economic development, the population increase and the increase in the agricultural area, especially after the completion of the construction of Ethiopian Renaissance Dam, so suitable alternatives must be provided for irrigated water. This paper presents a hydrological study on groundwater for use in irrigation in Assiut Governorate, Upper Egypt, so that alternatives can be provided to the Nile River for water used for irrigation purposes and appropriate uses. The experiments were performed using an experimental form created to achieve the purpose of the study. The model consisted of a cascade aerator and a sand filter. A packed bed filter (PBF) was added to be filled with some media before the sand filter. The media that were used in the study were plastic balls (80 mm), gravel (5-8 mm) and coarse gravel (15-30 mm). The results showed that the use of water leads to improving the efficiency of groundwater and thus making it suitable for irrigation purposes. The results showed that by using this model with the addition of the media used in this study, the groundwater was improved by up to 90% and therefore it could be used for irrigation. Finally, it is believed that the results of this study are useful in hydrological studies of groundwater for conditions similar to the ones under which this study was conducted.**

Key words: Irrigation, Groundwater, Water Resources, Filter, Assiut.

I. INTRODUCTION

Water is considered as one of the most important national security issues in Egypt, past and present. Water is the biggest challenge for agriculture in Egypt, as water is one of the extremely scarce resources in the region. Egypt's primary source of water is the Nile River [1]. The Nile River is the world's longest river, serving eleven countries: Rwanda, Burundi, the Democratic Republic of the Congo, Tanzania, Kenya, Uganda, Ethiopia, South Sudan, Sudan, and Egypt, and it has caused many problems and disputes throughout history due to the difficulty of resolving all of the opposing parties supply [2] . In light of the government's endeavor to save water, the government has taken measures aimed at rationalizing the consumption of irrigation. Groundwater, as opposed to free surface water sources such as streams, reservoirs, or lakes, is generally characterized as water contained in an aquifer matrix beneath the surface in the saturated region [3,4].Based on present demand expectations, the water shortage will increase and the cur-rent water resources (surface water, renewable ground water, desalinated water, treated wastewater,…etc.) may not adequately cover the future needs [5]. Egypt's share of Nile River water would decrease due to the building of the Grand Ethiopian Renaissance Dam [2]. One of the solutions for water shortage will be through the optimal abstraction of safe groundwater especially from the deep water layers [6]. Moreover, groundwater is becoming very important as a buffer for alleviating water shortages under fluctuating supply or demand [7]. Unfortunately, many groundwater sites are polluted at concentrations that exceed the guidelines for use in irrigation, so it was important to have mechanisms that contribute to improving the groundwater that can be used for irrigation [8]. There are many things that control groundwater in terms of quality and quantity, such as the type of layers and the rates of rainfall, evaporation and leaks resulting from irrigation and drainage networks. The groundwater is found in Egypt in Nile valley, Delta, Western Desert and Sinai [3]. The purpose of this study is to present a study on improving groundwater and maximizing its use in irrigation to provide alternatives to the Nile River. This is presented in this paper under the following headlines:

- Materials and methods.
- Results and discussion.
- Conclusions and recommendations.

II. MATERIALS AND METHODS

A. The Model

The model's steps are as follows: filtration and aeration with a cascaded aerator. The model also includes a packed-bed filter (PBF), figure 1. The experiments were carried out using groundwater pumped from the well. A cascade aerator is used in this model. The flow velocity through the exit weir was 0.02 m/s. The use of water from outlet of cascaded aerator has the ad-vantage of not requiring an external air supply. The PBF is a 12-liter plastic tank with inlet and exit poly vinyl chloride (PVC) valves. The packaging media in the tank is 10 liters. The filter is the model's final component. The filter column is opaque so that algae does not grow on the tube walls. The material is polyvinyl chloride, its diameter is 20 cm, its height is 2.35 m, and therefore its surface area is about 0.0314 m^2. There is a collection tank for treated water at the lower. The bottom of the column has a perforated flat to keep the filter media from spilling out during filtration. There are 6 sampling points along the depth of the filter, each fixed point every 150mm, from the flat perforated bottom to the height of 900mm.

Filter backwash, overflow, raw water inlet, treated water outlet, and sampling is all handled by PVC valves and ports on the filter. At sampling points, water samples were obtained using water taps. The influent water was evenly dispersed over the filter surface by a fixed nozzle at the top of the filter. Since sand is readily available, cheap, and produces acceptable results, it was chosen as the filter medium. It was 400 mm depth of Sand 0.8-1.4mm with diameter effective size 1.18mm and the top layer was 350 mm depth of 0.8-1.4mm diameter. A 150 mm depth of supporting layer of Gravel 10-15 mm diameter was used under the above mentioned media.

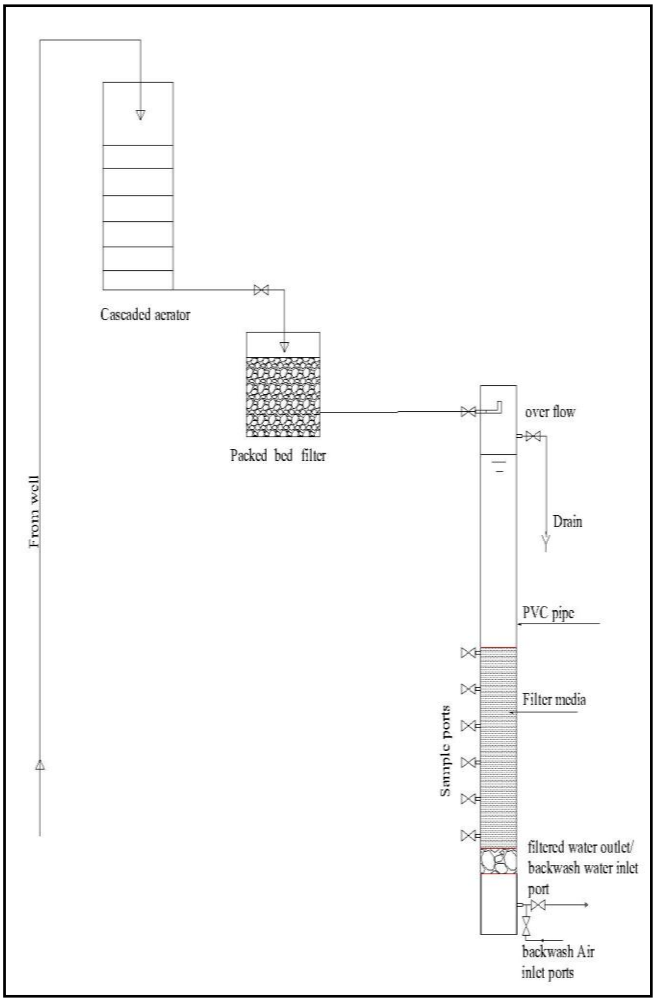

Fig1. Flow diagram of the model.

B. *Arrangements of Media*

The experimental investigation was carried out by using Plastic balls (80 mm), fine gravel (5-8 mm), and coarse gravel (15-30 mm) to achieve its objective, figure 2.

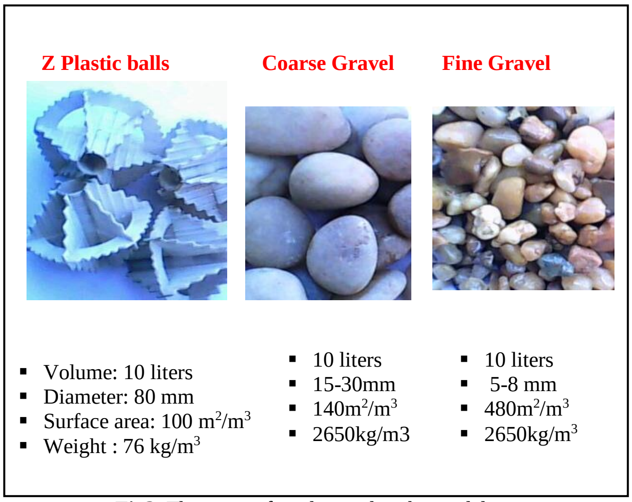

Fig2. The types of media used in the model.

C. *Study Site*

The study site was in Assiut Governorate, on both the eastern and western banks of the Nile. Figure 3 shows the study site, which is roughly between latitudes 26 ° 15 ° and 27 ° 10 ° N and longitudes 30 ° 40 ° and 31 ° 30 ° E. Assiut Governorate has a population of about 4 million people, with 73 percent living in rural areas and 27 percent in urban areas [9 , 10 , 11].

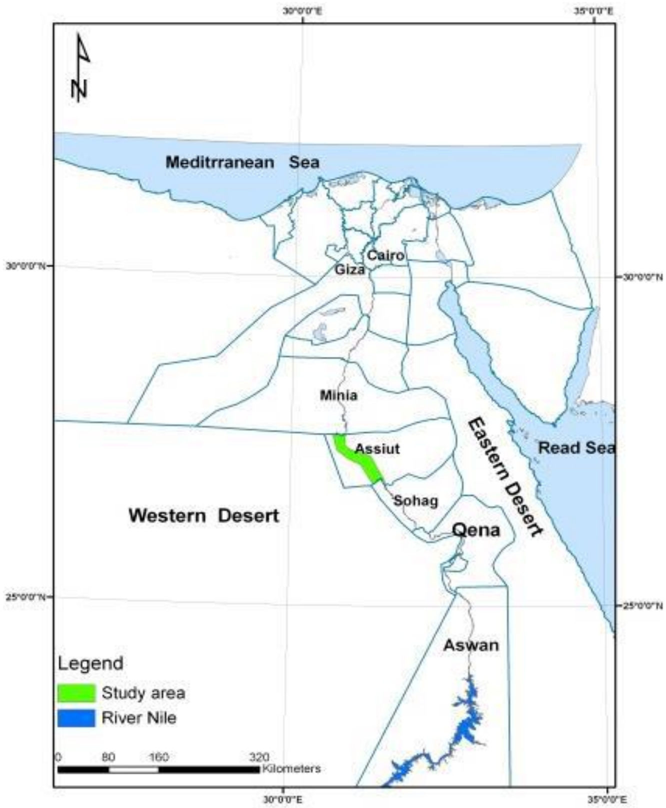

Fig3. Map of location study area in Assiut

D. *Data Collection*

Groundwater samples from various parts of the study site were subjected to certain measurements and analyses. Samples were collected from 49 wells at the study site. The location of the wells is depicted in figure 4. Water samples were collected every day from inlet and outlet through sampling points, collected in Polyethylene (PE) bottles and send to the Laboratory [12]. Measurements were taken for both of PH, Fe, Mn, Do, and ORP.

III. RESULTS AND DISCUSSION

A. *Climate*

The average temperature throughout the year for the study area is 22.1 C°, where the minimum temperature is 14.7 C° and the maximum temperature is 29.5 C° (Assiut Meteorological Station 2015 –2020). The average rainfall is around 0.07 mm / month, while the average relative humidity is 38%. The average of relative humidity is 38%. The average value of evaporation is about 13.71 mm/year, **Table** 1 [9, 13]. The climate in the study area is clearly hot, arid, and semi-arid.

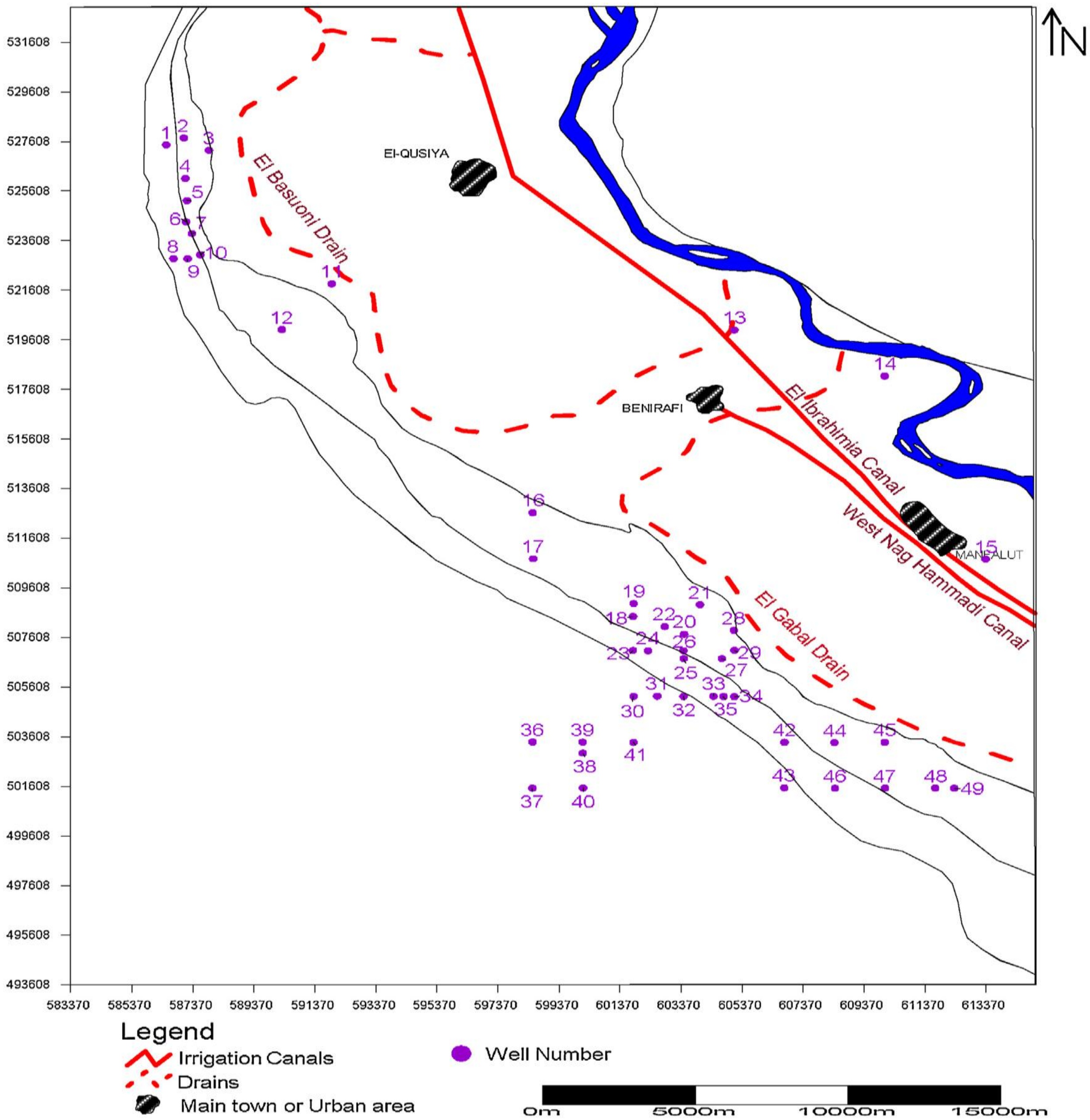

Fig4. Location of wells.

Table 1- Climatic data averages for study area (Assiut Meteorological Station 2015–2020)

Month	Min Temp (C°)	Max Temp (C°)	Wind (m/s)	Evaporation (mm/day)	Rainfall (mm/month)	Max rainfall (day/mm)
Jan	5.5	18	5.6	6.39	0.4	0
Feb	6.5	21.6	6.4	8.52	0.18	2.5
Mar	10.1	25.6	8.6	11.83	0.07	1
Apr	14.9	31.6	8	16.14	0.07	2.5
May	18.9	35.3	6.8	19.92	0	0
June	21.4	37.4	7.2	21.84	0	0
July	22.2	36.8	7	19.47	0	0
Aug	21.9	36.3	6	17.74	0	0
Sep	19.6	34.2	7.2	16.01	0	0
Oct	16.8	31.3	5.6	12.44	0.01	0
Nov	11.4	25.5	4.4	8.23	0.01	0
Dec	7.2	21	4.4	5.99	0.12	0.1

B. *Hydrogeological Study*

Canals and drains in the region have a very important role in the study. Egypt is located in the north of the African continent, within the arid region. Egypt is one of the countries with little rainfall, but it is sometimes subjected to flash floods and storms, especially during the winter season, and this occurs in some areas. Groundwater is formed through the seepage of rain or surface water in rivers or lakes into the layers of the earth through the microscopic pores of the soil and rocks until it reaches the rock formations that contain water known as aquifers, and this is known as the groundwater recharge process, which expresses the amount of the water that fills the aquifer during a certain period of time, and it often occurs in areas where the aquifers are exposed or close to the surface of the earth [14, 15]. The depth of the groundwater varies from one location to another, ranging from 2-6 m in the young alluvial plain to more than 20 m in the ancient sedimentary plains. The direction of groundwater flow is generally north. In the Nile Valley and the surrounding desert fringes, the quadruple aquifer has a broad geographical distribution. It is made up of granulated sand as well as gravel with clay. The aquifer is classified as either unconfined or semi-confined. The aquifer is partly covered by semi-permeable silty clay layers and the Nile Valley's middle portion, which is considered semi-confined, figure.5 (a, b) [16, 17].

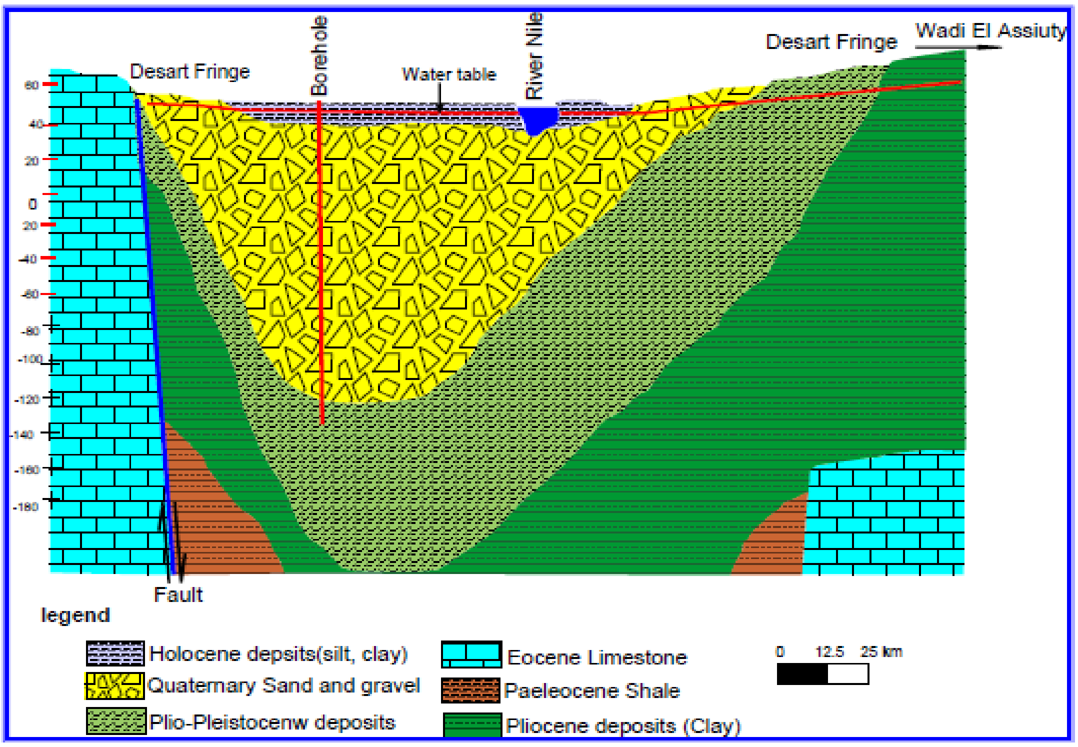

Fig. 5.a. Cross Sections of Hydrogeological

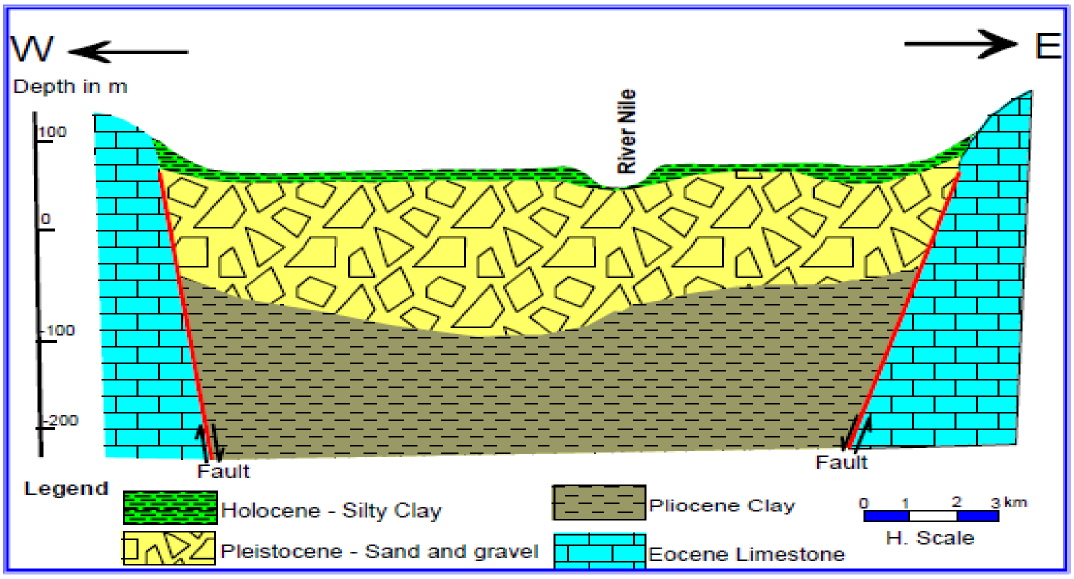

Fig. 5.b. Cross Section Hydrogeological of South Assiut

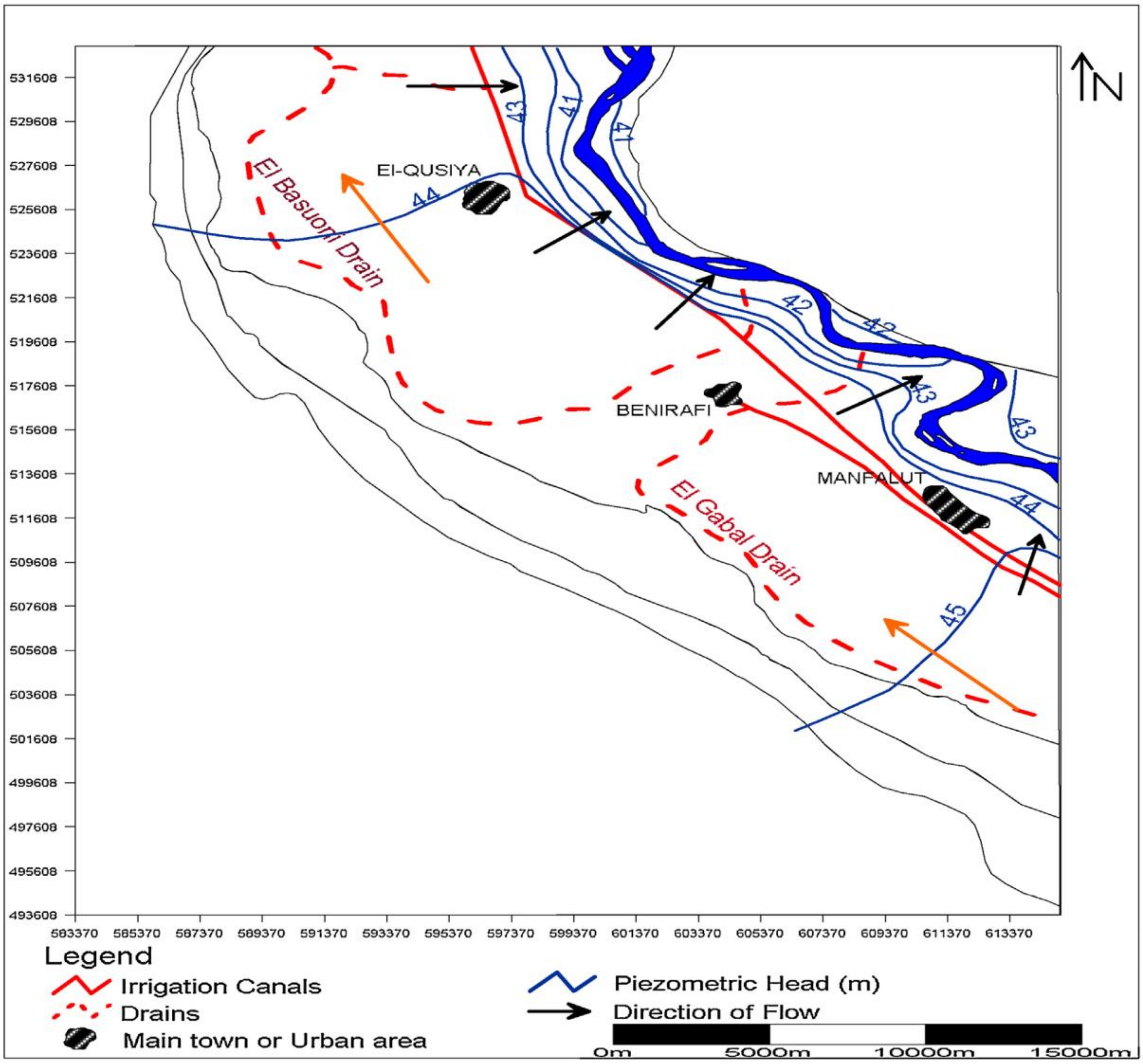

Fig. 6. The groundwater levels and direction of flow.

Figure 6 shows the control lines of a level in the groundwater in the region west of the Nile River, and it is clear that the water table descends in a longitudinal way towards the Nile from the level of 44 m to 41 m the groundwater flows from south to north from 45 m to 44 m.

C. *Packed Bed Filter (PBF),Its Impact on the Removal Efficiency*

As mentioned above, three types of PBF media have been tested. Two sizes of gravel, in addition to plastic balls. The PBF was added to the model to improve the overall system removal. Figure 7 illustrates the effect of the use of different media; gravel (size15– 30 mm), gravel 5 – 8 mm) and plastic media; in the PBF on the removal efficiency of Fe.

It was noticed that the addition of PBF with all kinds of backing media to the removal system improve the removal of Fe significantly [18]. Also, it was noticed that gravel with particle sizes in the range of 5-8 mm diameter provides the lowest effluent Fe concentrations after PBF, which means highest removal efficiency of Fe with an average value of 75.3%. However, less removal efficiencies were obtained using other media, average removals of 70.4% and 66% were obtained using plastic balls and gravel with particle sizes of 15-30 mm, figure 7.

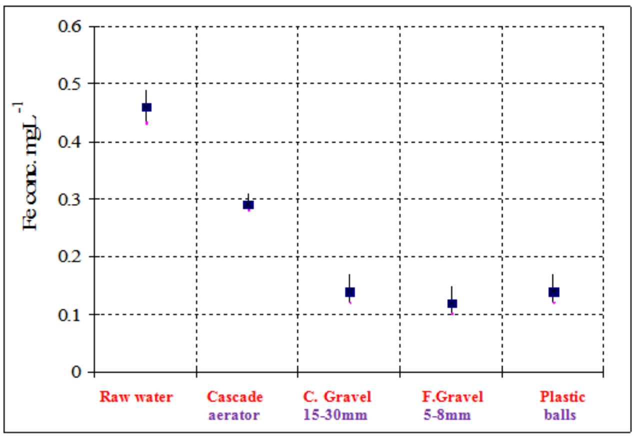

Fig. 7. Changes in Fe concentration after cascade aerator & PBF at different PBF media

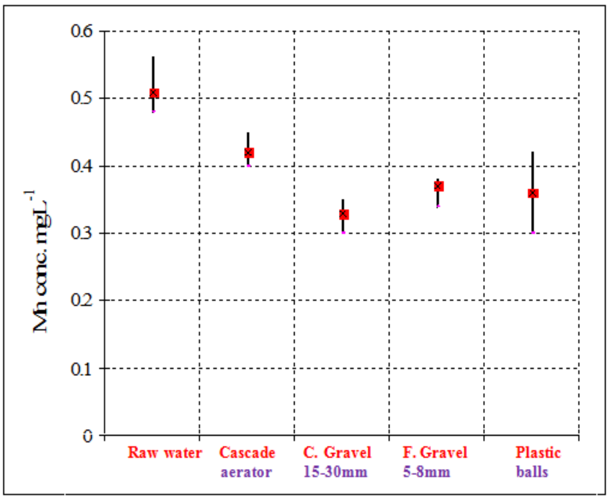

Fig. 8. Changes in Mn concentration (mgL^{-1}), after cascade aerator & PBF at different PBF media.

Also, it was noted that oxidation and removal efficiency of Mn due to PBF was negligible. Removal efficiencies of 9.3 % to 24 % were observed, figure 8. The weight of the plastic balls was found to be approximately 76 kg/m^3. This is compared to 2650 kg/m^3 for the gravel media. Therefore, plastic balls are recommended for use in the PBF. They can reduce the construction cost of the packed bed filter. Also, they are easier in handling and maintenance. In addition, plastic balls provide acceptable removals of Fe (up to 70% in average).

It was obvious that the addition of PBF to the model was more efficient to Fe removal than Mn removal, as Mn is more difficult to remove than iron [19].

It is believed that media with higher surface area increase the contact area between air and water and therefore, increase the diffusion of oxygen to water. This will result in the increase in oxidation of Fe.

D. *Dissolved Oxygen (DO) and Oxidation Reduction Potential (ORP) Relationship*

The evolution of ORP, pH and DO concentration for raw, aerated and filtered water was summarized in **Table** 2. There was no significant change in water pH among raw, aerated and filtered water. It was ranged between 7.10 and 8.03. It was noted that ORP values of raw water are very low and cannot be used to irrigate some crops.

After aeration DO doesn't change significantly, may be due to the consumption of some oxygen in aerobic oxidation of Fe and Mn. Also it was noted that ORP increased after PBF rather than the cascade aerator.

E. *Integration of PBF with Filtration*

Tables 3 and 4 show the removal results of the model operated in a continuous flow mode, without using PBF and with PBF containing Plastic balls.

Table 2. pH, ORP and DO changes in raw (well) water, aerated water and filtered water.

Run	pH			DO(mgL^{-1})				ORP(mV)			
	Raw water	Aerated water	Filtered water	Raw water	Aerated water cascade	Aerated water PBF	Filtered water	Raw water	Aerated water cascade	Aerated water PBF	Filtered water
1	7.69	7.79	7.73	1.2	6.6	6.8	5.1	-17	23	85	282
2	7.74	7.32	8.02	1.0	6.1	6.4	4.4	-23	35	98	258
3	7.76	7.80	8.05	0.9	6.0	5.8	5.1	-18	32	106	270
4	7.59	7.30	7.65	1.2	5.9	6.2	4.9	-28	19	92	287
5	7.72	7.68	7.50	1.1	6.3	7.0	5.3	-22	22	85	238
6	7.56	7.63	7.27	0.9	5.6	5.9	5.4	-46	37	115	288
7	7.50	7.54	7.09	1.3	5.1	5.8	4.7	-34	21	93	249
8	7.10	7.47	7.23	1.2	5.9	6.2	4.4	-29	43	106	252
9	7.35	8.03	7.82	0.8	6.2	6.1	4.8	-38	23	89	275
10	7.45	7.88	7.42	1.3	6.3	6.4	4.4	-44	18	78	269
11	7.15	7.93	7.63	1.4	5.4	6.0	4.6	-36	33	91	251
12	7.25	7.87	7.80	0.9	5.2	5.9	5.0	-32	37	83	259
13	7.52	7.60	7.20	1.6	4.9	6.7	5.9	-30	35	95	298
14	7.00	7.20	7.35	1.5	5.0	5.3	4.7	-26	36	89	278
15	7.30	7.45	7.70	1.3	5.6	5.4	4.6	-21	38	99	281
16	7.40	7.50	7.90	1.2	5.3	5.6	4.3	-19	44	101	259
17	7.10	7.35	7.47	0.9	5.6	5.8	4.9	-21	40	112	278
18	7.00	7.26	7.60	1.1	6.1	6.2	5.0	-27	41	90	292
19	7.30	7.38	7.70	1.2	6.3	6.0	4.3	-31	46	86	283

Table 3. Removal of Fe and Mn in a continuous flow mode, without using PBF.

Run	Fe mgL^{-1}		% Removal	Fe mgL^{-1} Filtered water	% Total Removal	Mn mgL^{-1}		% Removal	Fe mgL^{-1} Filtered water	% Total Removal
	Raw water	Aerated water				Raw water	Aerated water			
1	0.661	0.436	34	0.233	70	0.51	0.462	9.8	0.035	93
2	0.789	0.742	6	0.457	42	0.488	0.453	7.2	0.076	84
3	0.698	0.563	19	0.34	51	0.496	0.458	8.1	0.094	81
4	0.723	0.651	10	0.31	57	0.472	0.448	5.1	0.12	75
5	0.454	0.321	29	0.218	52	0.523	0.502	4	0.034	93
6	0.398	0.321	18	0.198	50	0.411	0.399	2.9	0.015	96
7	0.763	0.448	41	0.311	59	0.46	0.452	1.7	0.021	95
8	0.775	0.552	29	0.333	57	0.451	0.449	0.4	0.024	95
9	0.782	0.563	28	0.338	57	0.401	0.394	1.7	0.041	90
10	0.754	0.612	19	0.389	48	0.66	0.554	18.2	0.052	90
11	0.582	0.433	27	0.157	73	0.369	0.366	0.8	0.05	86
12	0.564	0.338	40	0.217	62	0.543	0.54	0.6	0.042	92
13	0.449	0.395	14	0.211	53	0.469	0.461	1.7	0.039	92
14	0.448	0.398	11	0.31	31	0.482	0.47	2.5	0.04	92
15	0.454	0.31	32	0.298	34	0.501	0.499	2	0.039	91.7
16	0.523	0.368	30	0.331	37	0.484	0.484	0	0.041	91.5
17	0.544	0.389	28	0.237	56	0.435	0.428	1.6	0.033	92.4
18	0.621	0.452	27	0.302	51	0.51	0.5	1.96	0.045	91.2
19	0.541	0.42	22	0.182	66	0.563	0.56	0.53	0.011	98

Table 4. Removal of Fe and Mn in a continuous flow mode, using PBF.

Run	Fe mgL^{-1}		% Removal	Fe mgL^{-1} Filtered water	% Total Removal	Mn mgL^{-1}		% Removal	Fe mgL^{-1} Filtered water	% Total Removal
	Raw water	Aerated water				Raw water	Aerated water			
1	0.73	0.24	67.8	0.11	84.9	0.99	0.79	20.2	0.051	94.8
2	1.12	0.30	72.8	0.12	89.3	2.63	2.00	23.9	0.020	99.2
3	2.79	0.66	76.3	0.28	90.0	5.02	3.63	27.7	0.041	99.2
4	3.36	1.02	69.7	0.19	94.3	6.94	5.60	19.3	0.143	97.9
5	3.40	0.75	78.4	0.24	92.9	7.67	5.79	24.5	0.094	98.8
6	9.54	3.88	59.3	0.82	91.4	11.00	8.75	20.5	0.605	94.5

F. *Fe Removal*

The removal efficiency of the filtration system without using PBF is shown in **Table** 2. It was noted that Fe maximum removal of 40% can be achieved with aeration step by cascade aerator in comparison to 78% of Fe removal with the using of PBF, **Table** 4. This is resulted in increasing total Fe removal after bio filtration to about 94% in case of using PBF in comparison to about 73% of total Fe removal after filtration system.

The majority of the Fe extracted may be due to oxidation in the cascade aeration and PBF, as seen in Figure 9. Fe oxidation begins immediately (after the aeration stage) in the supernatant and filter bed in the presence of oxygen, and the adsorption-oxidation process will also occur in the filter bed, meaning that Fe removal is likely to be supplementary to traditional physico-chemical Fe removal [20].

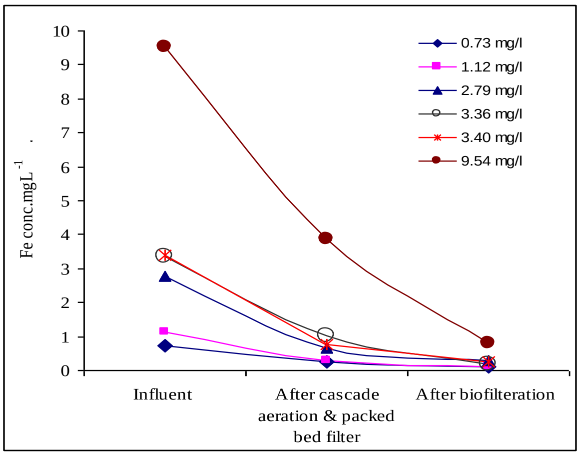

Fig. 9. Fe removal efficiency of the filtration system using after each stage.

G. *Mn Removal*

In case of Mn, the removal efficiency after aeration step in general was low and didn't exceed about 27%, **Tables** 3 and 4. It is also noted that there is no significant change in removal efficiency in case of using PBF or not using it. However, high removal efficiency can be achieved in both cases by the filter which reached to about 99 % removal of Mn. This indicates that the removal of Mn, unlike the Fe removal, takes place mainly through the filter, Figure 10. The findings demonstrate the significance of both PBF and the filter. As a result, Fe and Mn removals are known to be accomplished in the same facility, and the implemented method is capable of removing Fe and Mn concentrations of up to 9.5 mgL-1 and 11.0 mgL-1, respectively.

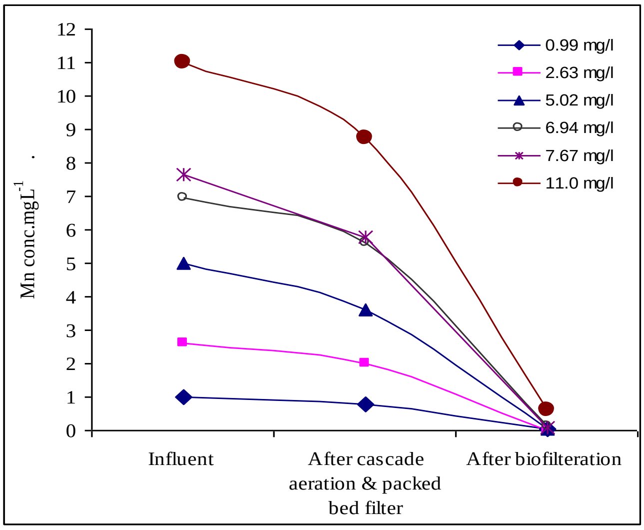

Fig. 10. Mn removal efficiency of the filtration system after each stage.

IV. CONCLUSION& RECOMMENDATIONS

From the previous analysis of the obtained results, the conclusions which have been reached are as follow:

- The results showed that the use of water leads to improving the efficiency of groundwater and thus making it suitable for irrigation purposes.
- Groundwater quality is poor in urban area, but wells typically show positive measures of irrigation water quality.
- The largest aquifer is made up of medium to coarse sand and gravel, as well as clay.
- Dependence on groundwater to solve the water poverty problem.
- Rising groundwater levels result in major problems in increasing soil salinity.
- Using plastic balls with a diameter of 80 mm achieved satisfactory results by about 71%.
- It was noted that when DO concentration in raw water rose after aeration, ORP values increased and seemed to suggest a proportional relationship.
- Plastic balls are recommended for use in the PBF due to their light weight, easier in handling and maintenance.
- Finally, it is believed that the results of this study are useful in hydrological studies of groundwater for conditions similar to the ones under which this study was conducted.

NOTATIONS

The following symbols have been adopted for use in this paper:

- DO = Dissolved oxygen;
- Fe = Iron ;
- Mn = Manganese ;
- ORP=oxidation-reduction potential;
- PBF = Packed bed filter;
- PE = Polyethylene and
- PVC = poly vinyl chloride.

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