MODELING OF BIOLOGICAL CONTAMINATION OF GROUNDWATER AT HELWAN DISTRICT

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ABSTRACT

The protection of the environment against contamination and the need for water are two of the major concerns of the world today. The contamination of ground water is a subject that is strongly connected to both items. In this work, a domain with groundwater that is strongly contaminated from different sources is considered. The contamination process is studied both theoretically and experimentally. In the theoretical approach the contamination variation with time and location is studied using two mathematical models one for fluid movement and the second for contaminant transport. A part of the experimental and field work results are used to calibrate the models and evaluate of hydraulic parameters. The rest of experimental results are found to be in good agreement with the results obtained from the mathematical model.

Keywords: Biological contamination, contaminant transport, hydraulic conductivity, mathematical models, groundwater pollution

INTRODUCTION

The groundwater has the advantage over surface water of being less dependable on quick variation on weather conditions. Its potential depends on the average values of its sources over long periods of time rather than on yearly or season basis. On the other hand, its contamination is considered more disastrous as the contaminant affects the whole reserves or at least a major part of it [1].

The sources of groundwater [2], include among other things, the following: leakage from waste water networks, disposal of industrial wastes, leakage from landfills, leakage from petrol and oil change service stations and fertilizers applied in agricultural land.

In Egypt there is a law to protect the Nile from the sources of contamination including groundwater [3]

The Helwan District is chosen as it receives a strong contamination share from almost all the above mentioned sources [4].

AREA OF STUDY

The chosen area to conduct the study lies at the eastern Nile bank [5]. It starts 15 km south of Cairo and extends further south for a length of 15 km. The region looks almost like a rectangular strip with a length of 15 km and an average width of 4.5 km.

The study area covers about 68 km^2 with the River Nile acting as its western boundary. The region occupies parts of Ein Helwan, Helwan and El-Tebin districts. It can be considered as partly industrial, partly urbanized. It has tourist attractions and agricultural lands as well. Two natural springs as well as industrial factories exist in the region.

The area lies in the River Nile plane. A general slope of the land surface takes place from the east to the west. The land level varies between 50.0m above sea level and 17.5m above sea level. The western part, which is nearly adjacent to the River is mainly cultivated dark clayey land. As one moves eastwards, some hills of sand and gravel appear. The top soil layer around the Nile banks can be treated as unconfined water bearing formation with variable thickness. The thickness varies from close to zero up to 50 m in some locations [6].

FIELD AND EXPERIMENTAL WORKS

The field hydraulic conductivity is measured in the 14 locations shown in Figure 1. This is done using the Auger hole method. The subdivisions of the study region and the corresponding K values are presented in the same figure.

Also soil samples are collected from the 14 boreholes at a depth of 2.00 m below the groundwater level. The collected samples are tested in the laboratory where the water content values are determined experimentally.

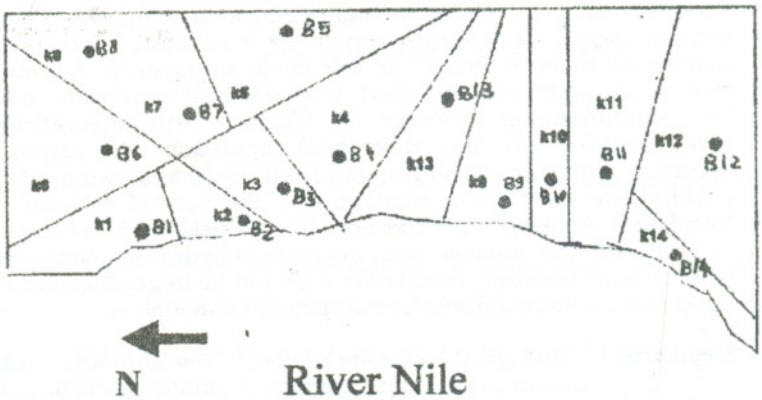

Figure 1 Location of boreholes and field hydraulic conductivity in the subdivisions

The total coliform is measured in Mpn/100 cm^3. The organic pollutants, BOD, COD, turbidity, total suspended solids and total volatile solids, are measured. The surface water appears in the region of study as a boundary which is the east bank of the River Nile. It appears also in El-Khashab Canal which passes through the area and in Ein Helwan springs [7]. Water swnples were collected and tested from the three free water bodies. The results obtained from tested samples are found in Table 1

Table 1 Biological analysis of surface water

Sample Location	Total Coliform	Bod mg/L	COD mg/Liter	Turbidity mg/Liter	Total Suspended solids mg/Liter	Total Volatile solids mg/Liter
7'	43×10^2	26	120.96	17	170	170
11'	24×10^3	30	103.68	39	1400	860
15'	4×10^3	54	656.64	207	420	240

7' Surface water sample from Ein of Helwan natural Spring
11' Surface water sample from El-Khshab canal .
15' Surface water sample from Storm Drain

MATHEMATICAL MODELING

The contaminant is transported through the groundwater body through two processes, namely advection and dispersion. This implied the use of two mathematical models. In the first model [8], the fluid flow is considered. The advection component of the contaminant transport is equivalent to fluid particles at the same location. This is done using the equations of fluid flow through porous media. In the second model [9], the dispersion component is calculated using a model that is based on differential equations of contaminants diffusion.

In both models, 2-dimensional non-steady state conditions are adopted. The fluid flow may be fully or partially saturated. The method of finite elements is used in both models. The basic data regarding the hydraulic properties are obtained from field and experimental works. Accordingly, the area is divided into 14 divisions. Each subdivision has it's own material properties.

Figure 2. shows the groundwater contour lines at mean Nile water levels. As it is obvious from simple logic, the groundwater distribution in this map leads to a flux value of groundwater drained in the Nile that lies between the maximum and the minimum Nile water levels, 52.226 m^3/d.

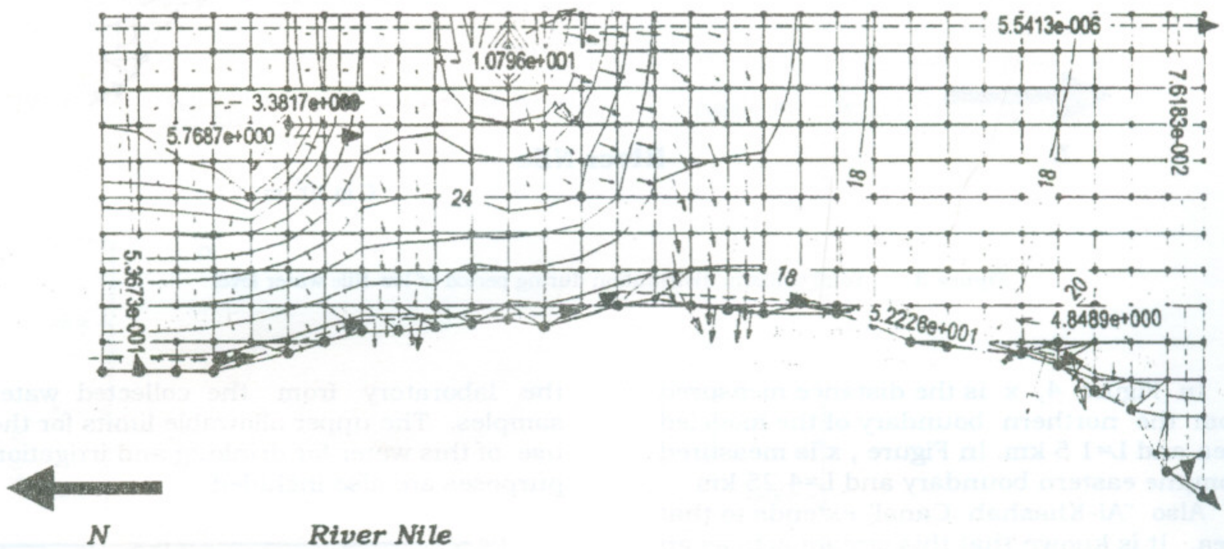

Figure 2 Groundwater contour map at mean nile water level

More than 70% of the groundwater in the area has a concentration value bigger than $0.4x10^5$ Mpn/(100 cm^3), while about 50% of the area has a concentration value bigger than 1.4x105 Mpn/(100 cm^3) which is considered a very high concentration.

In the case of low Nile water level shown in Figure 3, the concentration of total coliform contained in the groundwater and seeping to the Nile within the model lies around $1.2558x10^7$ Mpn/(100 cm^3). Analysis of the surface water samples from the Nile at a location adjacent to the study area showed the existence of total coliform in the surface water. The lines of equal total coliform concentration on the map show extension of the contaminant along the other 3 boundaries of the model not only on the Nile boundary.

A comparison between the two total coliform flux rates across the two vertical sections z_1- z_1 and z_2- z_2 indicated in 7.16 leads to the fact that a strong total coliform producing source exists in the range between them In the mean time,- from the physical model, it can be seen that this strip is relatively high populated in comparison with other parts of the model.

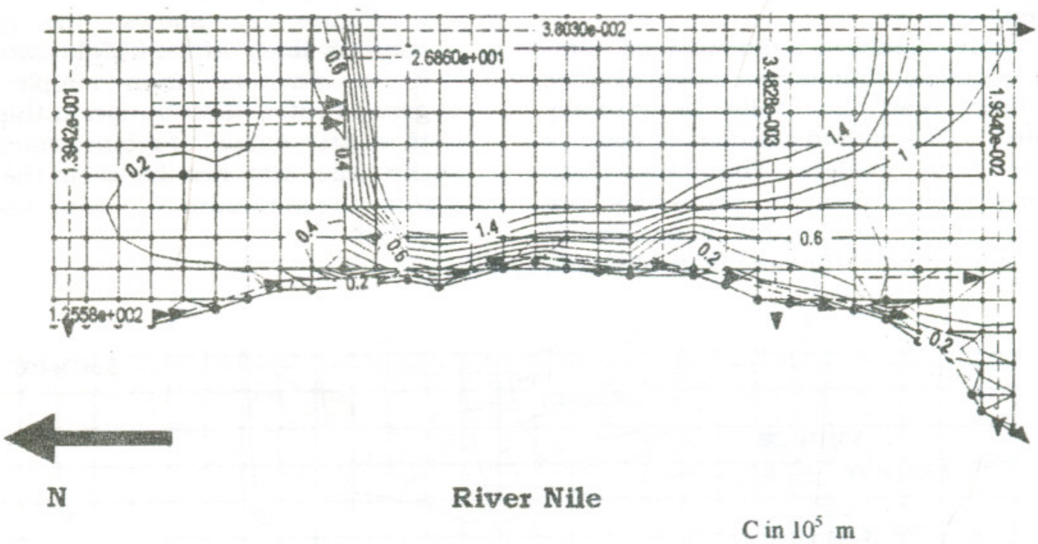

Figure 3 Total coliform distribution during period of low Nile water level

In Figure 4, x is the distance measured from the northern boundary of the modeled area and L=1 5 km. In Figure , x is measured from the eastern boundary and L=4.25 km

Also "Al-Khashab Canal" extends to that area. It is known that this stream acts as an irrigation canal in some areas and as a drain in other areas. Hence, although it is supposed to act as an irrigation water body all the way, yet sewage water and industrial water seeps or intentionally are disposed in it. In the part where it acts as a channel, the contaminated fluid seeps into the groundwater with all its contaminants.

INFLUENCE OF CONTAMINATION ON WATER USE

This section is devoted for the investigation of the influence of contamination on the use of the groundwater for irrigation and drinking purposes. The presented comparison is conducted using the water quality criteria according to Middlebrooks (8).

Figures 6 to 8 contain a representation of the contaminant content as measured in the laboratory from the collected water samples. The upper allowable limits for the use of this water for drinking and irrigation purposes are also included.

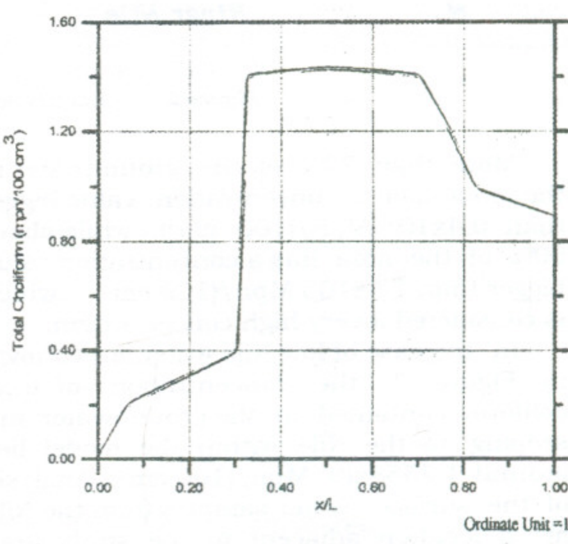

Figure 4 Total coliform distribution along section x-x

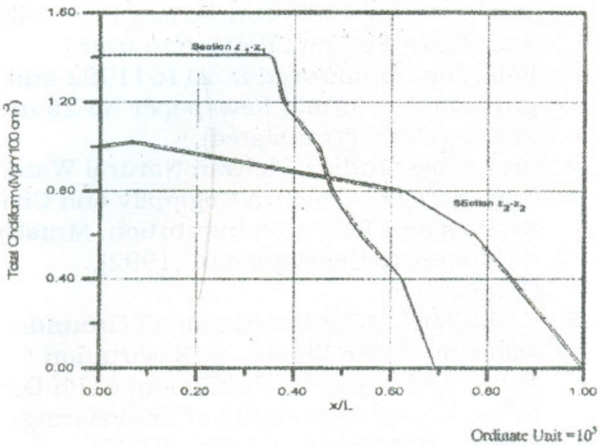

Figure 5 Total coliform content across vertical section z_1-z_1 and z_2-z_2

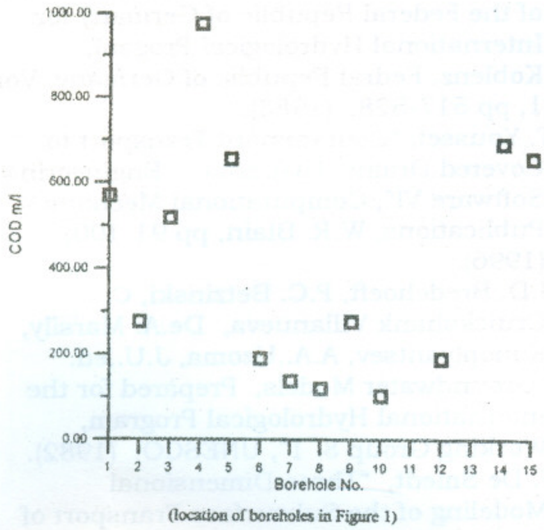

Figure 6 COD content in groundwater

The previous graphs contain the information needed regarding the possibility of the groundwater use. The following items are of importance: there are BOD, COD and total Coliform contents in all samples. This assures the existence of organic contaminants in the groundwater due to the last remark. the groundwater in the area in the present condition can't be used neither for drinking nor for irrigation without proper treatment.

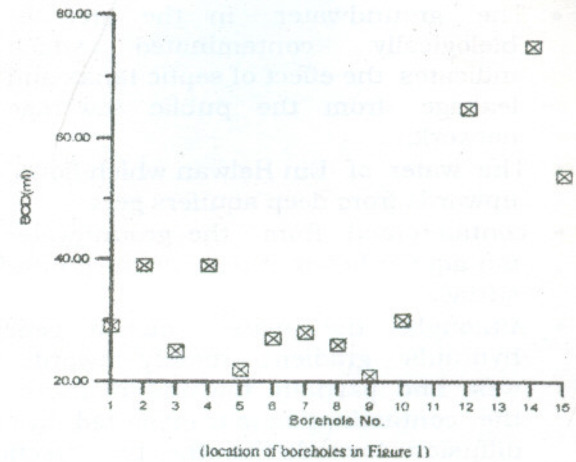

Figure 7 BOD content in groundwater

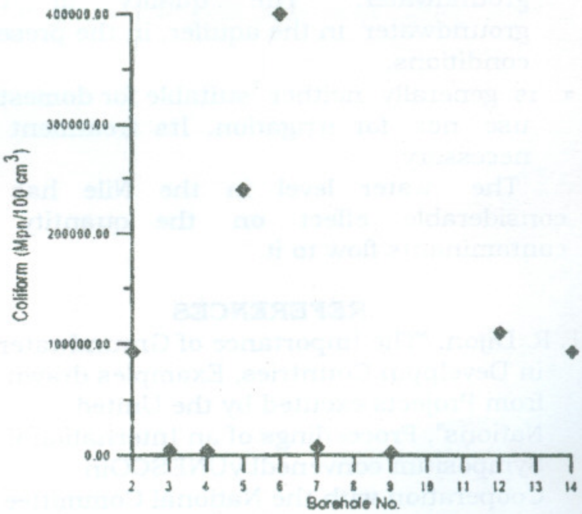

Figure 8 Total coliform content in groundwater

CONCLUSIONS

The obtained conclusions as related particularly to the study area include:

- The River Nile acts as a drain to the whole area of study.
- The rate of seepage to the Nile is inversely proportional to the Nile water level. However, the difference between the flux values during high and low Nile water levels is not great.
- The groundwater in the area contains a lot of contaminants that can be only classified as liquid industrial wastes

- The groundwater in the area is biologically contaminated which indicates the effect of septic tanks and leakage from the public sewerage network.
- The water of Ein Helwan which flows upwards from deep aquifers gets
- contaminated ftom the groundwater top aquifer before it reaches the ground surface.
- Although, the water has a general hydraulic gradient mainly towards the west and partially towards the north, yet the contamination is transported through diffusion towards the other two directions as well. The Nile receives the lions share of all contaminants that appear in groundwater. The quality of the groundwater in the aquifer, in the present conditions,
- is generally neither suitable for domestic use nor for irrigation. Its treatment **is** necessary.

The water level in the Nile has a considerable effect on the quantity of contaminants flow to it.

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محاكاة التلوث البيولوجى للمياه الجوفية بمنطقة حلوان

فاطمة شلتوت و تهانى يوسف
قسم الهندسه المدنيه - المطريه - جامعة حلوان

ملخص البحث

تحظى موضوعات حماية البيئة والنقص فى موارد المياه باهتمام كبير، ويرتبط بموضوع تلوث المياه الجوفية بكى المجالين ارتباطا وثيقا، وفى هذا العمل تمت دراسة نظرية وميدانية لتلوث المياه الجوفية بمنطقة حلوان حيث تتوافر مصادر التلوث ما بين مخلفات المصانع وشبكات المجارى المغطاة والمكشوفة وتسميد التربة والتسرب من مدافن المخلفات الآدمية, وقد تم عمل قياسات حقلية وإجراء تجارب معملية لتحديد خواص الطبقات الحاملة للمياة ومعدلات التلوث بها، وقد استخدمت النتائج فى مغايرة وتغذية النماذج الرياضية التى تحاكى حركة كل من المياة الجوفية والملوثات داخل التربة، وقد استخدمت النماذج لتحديد معدل توزيع نسبة الملوات بالمنطقة وكذلك معدل تلوث مياه النيل من جراء اتصاله بالطبقة السطحية للمياه الجوفية.