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EFFECT AND EVALUATION OF INDUSTRIAL WASTEWATER DISPOSAL FOR BASRAH PLANTS BY DIRECT INJECTION

Ayman A. Hassan[1]

[1] Lecturer, Dept. of Civil Engineering, College of Engineering, University of Basrah, Iraq. Email: aymanalhijaj@gmail.com

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ABSTRACT

Wastewater effluent of plants is frequently disposed via injection wells or drain fields into the geological substrate near surface water streams. In this study, we evaluated and specified the relationships between the plants wastewater disposal flow, concentrations, and the disposal injection wells distances from surface water stream for minimum harmful pollutants transport to the stream. The study area was Basrah fertilizes plant near Shatt-Al-Basrah stream. A completed representation for the study area parameters data were done to simulate the aquifer, surface water, pollutants disposal, and flow-transport system for the current state and the proposed injection wells systems. The simulation and evaluation study showed that the current disposal system is harmful to the stream and the best disposal system for the wastewater plant was the injection wells. The study also revealed that the best distance for the proposed fertilizes plant disposal wells must be located not less than 480 m from the river with an injection rate not more than 3600 m^3/day.

KEYWORDS: Injection Wells, Basrah fertilizes plant, Groundwater Pollution, MODFLOW

1. INTRODUCTION

The industrial wastewater disposal from plants that exist near water resources (Rivers, Seas, etc.) can be discharged directly into surface water and to the land. Each type of disposal has its own permitting process and requirements that must be met. However, in areas near streams or rivers, it can be unclear which category must applied. The State Board of Health gradually adopted rules and enforced the use of septic systems during the mid of the 1960's to protect the public health. Components of these septic systems included a septic tank with effluent disposal achieved using a drain field or injection well (Tom, 2008). An injection system or underground injection system means "A well, improved sinkhole, sewage drain hole, subsurface fluid distribution system or other system or groundwater point source used for the subsurface emplacement or discharge of fluids" (Internal Management Directive, 2007).

Disposal of industrial wastewater effluent by indirect discharge to surface water via groundwater Fig. 1 may be environmentally beneficial if planned, installed, and operated correctly, and if located under the right geographic, hydrogeological, and environmental conditions. The type of indirect discharge system should be match the specific conditions of the site.

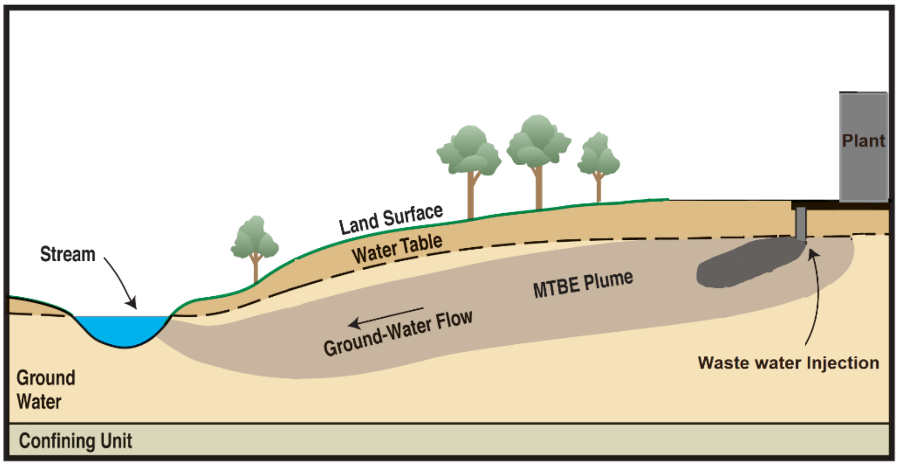


Fig. 1. Schematic representation for indirect industrial pollutants discharge to surface water via subsurface injection (Tom, 2008).

The benefits of using indirect discharge are: wastewater temperature may be reduced in groundwater to meet in-stream temperature standards. Therefore, stream flow volumes may be maintained. Some "polishing" of the wastewater, such as reducing total metals or removing residual chlorine. Through natural geochemical processes may occur within the soils and aquifer containing groundwater; and if a land application component is used in the design, nutrients in wastewater may be beneficially reused by plants, therefore reducing the nutrient load for a mandated total maximum daily load (Internal Management Directive, 2007).

Basrah province is a good example for studying industrial sewage indirect disposal to surface water because it contains more than 20 plants, which located on surface water streams. Discharge of industrial sewage into cesspits, shallow holes, or directly into the adjacent surface water was common methods of sewage disposal in Basrah City. Therefore, the aim of this work is: (i) simulating and studying the contaminants transport from the plants area to the aquifer; (ii) the prediction of the contaminants transport concentration in subsurface and surface water regions and (iii) evaluating the water quality of stream due to indirect discharge of pollutants (from plants) to surface water via groundwater and obtaining the best disposal distances.

2. STUDY AREA

The study site was Basrah fertilize plant area where it is located in the South East of Iraq in Basrah province which is near Shatt-Al-Basrah stream between 777220 to 778080E and 3343070 to 3343640N, with an area of 300000 m^2 and with average surface altitude of 20 m above mean sea level. The Basrah fertilize plant examined in this paper is located in Khor Al-Zubair region within Al-Zubair district, 75 km southwest of Basrah. Fig. 2 shows the study area and the plant site with respect to surface water stream, where the horizontal dimensions of about 600 x 500 m and the plant exist at a distance of 400 m from the surface water stream. The plant disposed effluent via surface pond located at a distance of 300m from Shatt Al-Basrah stream.

Groundwater in the study area occurs in an unconfined aquifer of alluvial deposits, which is composed mainly of sand and gravel (Naseer, 2009). The aquifer is a part of Dibdibba aquifer. The upper part of Dibdibba is Sandy formation, with high drainage soil conditions. Morphologically, the area of study is a flat plain that generally slopes towards North East of the area. The principal direction of the groundwater flow is from the South-West to the North East towards Shatt Al Basrah stream with average of hydraulic gradient of 0.0018 (Alaa, 2007; Hazim, 2000).

Based on the climatic data of Al-Basra meteorological station for the period 1980-2015 for the study site is characterized as hot, dry climate and high wind velocity in summer, and cold, humid with little to moderate rainfall in winter. In general, the area is located within a semi-arid zone with an average annual precipitation of 152 mm/year (Naseer, 2009).

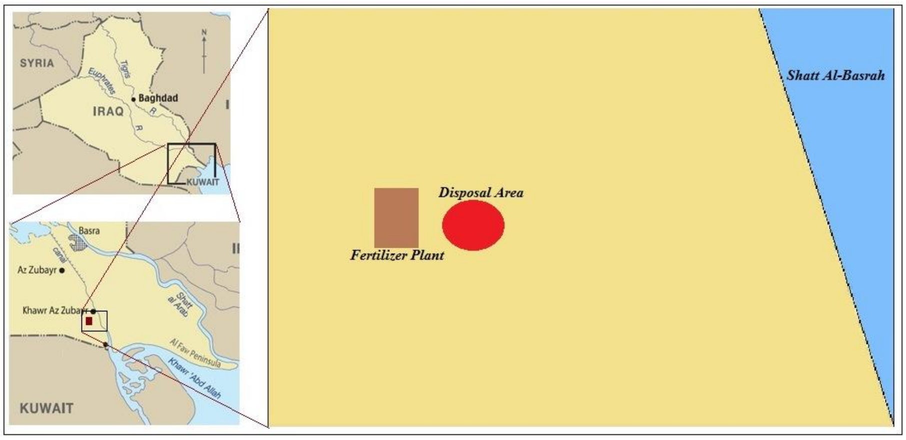


Fig. 2. Location map for the study region of Basrah fertilizer plant site [google map].

3. METHODOLOGY

The numerical models, MODFLOW2005 and RT3D 2.5 (McDonald, 1998; Langevin, 2006) were simulate and predict the time and spatial variation of pollutants transport from the waste discharge source to the stream through the soil and to know its features. MODFLOW2005 is a powerful software package for flow simulations. This software consists of input, run, and output sections. In the first section, characteristics of the aquifer and groundwater and boundary conditions were assigned for software. Run section is designed to translate an input section in the standard input for simulation. Output illustrates that the results of simulation included of water levels, flow, and so on.

RT3D2.5 is a program for simulating reactive multi-species mass transport in three-dimensional groundwater aquifers. RT3D2.5 was developed first by Clement, (1997) for the Battelle Memorial Institute, Pacific Northwest National Laboratory; it was subsequently released into the public domain and quickly became an accepted standard for reactive transport modeling. (McDonald, 1998).

The researcher uses these techniques to predict the fate and transport of pollutants from Basrah fertilizer plant discharge to the surface water stream at the current state, then simulating the proposed disposal by injection wells. Finally, estimation the best distance for injections that it might be helpful to control pollution in these regions.

4. SIMULATION MODEL SETUP AND MODELLING DATA

The constructed model consists of the surface water stream, the source of pollutants from the fertilizer plant and the connected porous media between them. The field works were conducted in this study including detailed field surveys to investigate all aquifer characteristics. Many wastewater and surface water samples were collected from the fertilizer plant discharge to know the concentrations of source pollutants. In the monitoring process, different devices, such as level, tape, sounder, and GPS were used to measure the groundwater level. Two points were selected for sampling: the first point represents the sewage discharge site (main pollutants source), and the other point represents the surface water at Shatt-Al-Basrah river near to the plant Fig. 2.

The sewage and surface water samples were collected in clean plastic bottles of 1.5 litters and then transported to the laboratory for chemical analysis. All samples were analyzed for relevant physical-chemical parameters according to internationally accepted procedures and standard methods (APHA, 2005). The parameters were analyzed included: sulfates (SO_4), chloride (Cl), total dissolved solids (TDS), pH, phosphate (PO_4), Oil, and nitrate (NO_3). Table 1 shows the average measured concentrations of selected pollutants from the pollutants source and surface water sampling points during the study period.

The selection of the contaminants to be modeled was based on screening the effective pollutant that relied on concentrations in site-specific source samples, susceptibility to natural attenuation and concentration limits in surface water. The screening indicated that PO_4 would be the most critical pollutants for surface water stream (Water Quality Standards Review, 2009). The phosphate was selected as an indicator for the numerical simulations where the other pollutants can be determined at any time and space proportionally from PO_4 concentrations, the PO_4 must not exceed 0.4 mg/l as per Iraqi standards (Water Quality Standards Review, 2009).

Table 1. Average measured parameters concentrations for pollutants source and surface water samples for the period of study (2016).

	Parameters concentrations (mg/l)						
	SO_4	**Cl**	**NO_3**	**TDS**	**pH**	**PO_4**	**Oil**
Fertilizer Plant disposal source	4632	3850	1.6	9700	8.5	5.5	19.5
Shatt Al-Basrah near the plant	1137	1210	0.05	22800	8.3	2.3	9.3

A conceptual model for the study area was constructed with a total effective area of 300000-m^2 and model thickness of 70 m. The model with a surface distance of 600 m x 500 m where it is extended toward the East and North bordered by Shatt Al-Basrah stream to get the best expression for boundary condition for river edge. For the study area aquifer, a regularly spaced, finite-difference model grid was constructed so that the y-axis represents the North and x-axis represent the East. The grid consists of 60 rows and 50 columns, regularly spaced grid in horizontal and longitudinal directions. Seven cells (layers) in the vertical direction with a constant thickness (ΔZ) of 10 m topping by land surface elevation. The bottom of the layer was set at an elevation of 50 m below the water table to ensure the assumed injection wells at full penetration within the model. The total number of model spaced cells is 21000 cells. Each cell is 10 × 10 ×10 m. The well package was used for aquifer stressing by injection the plant sewage to the aquifer at the proposed rates of wastewater disposal from the plant. Constant concentration was assigned to the sewage source injection site as a boundary condition of the model with a specified PO_4 concentration. A Neumann-influx boundary condition was assigned at the land surface, and the recharge package was used to represent the recharge of the aquifer (McDonald, 1998). The sources of the recharge are rainfall with the proportion of infiltration of 20% of rainfall (Al-Aboodi, 2003). The total period of simulation was chosen for 30 days and this period is divided into 15 stress periods.

Hydraulic aquifer parameters were estimated from field observations, laboratory testing, and soil investigation reports that were done for the areas at the study region projects [Soil Investigation Report for Rafidya]. According to the laboratory tests and historical data from the Basrah groundwater directorate and literature studies for the study aquifer, the values of hydraulic conductivity (K) were mostly within the range of 60-90 m/day and specific yield (Sy) of 15-20%. Some of aquifer hydraulic parameters, such as vertical permeability (Kv), and longitudinal and transverse dispersivities (αL and αT) were estimated from soil properties standards tables or from other researches done in Kuwait (Al-Rashed, 2010; Mukhopadhyay, 2002). The groundwater levels at present state were found at about 7-8 m depth from the land surface; Table 2 summarizes the study aquifer input parameters for the simulation model.

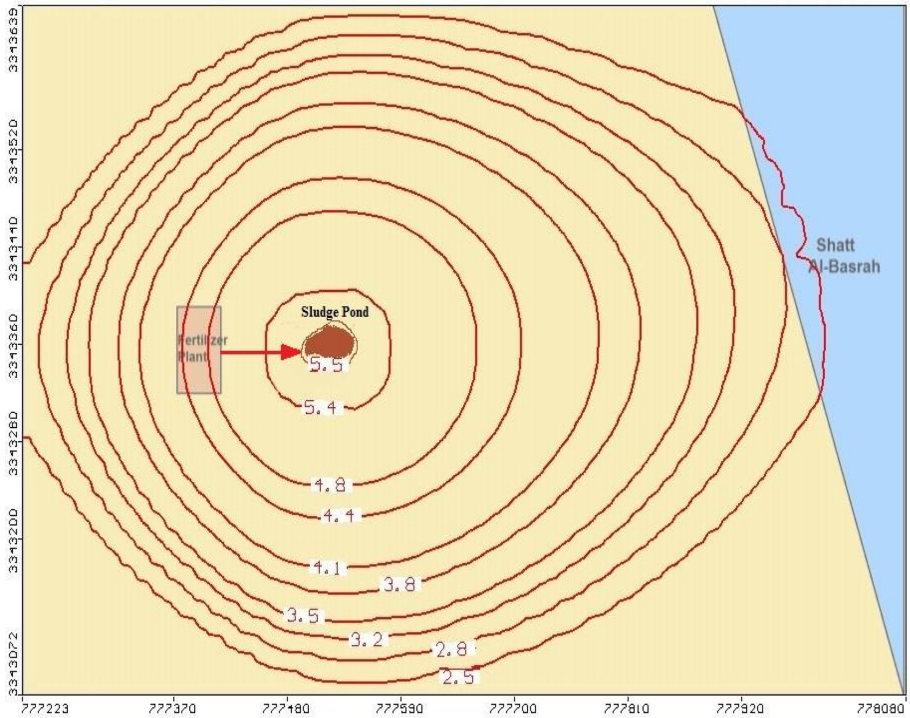
Table 2. Original aquifer parameters assigned for Khor Al-Zubair aquifer.

Parameter	Value
Hydraulic conductivity Kxy (m/d)	70
Hydraulic conductivity Kz (m/d)	45
Total porosity (%)	24
Effective porosity (%)	22
Specific yield	0.20
γ_s: Average soil dry density (Kg/m^3)	1.78
α_L : longitudinal dispersivity (m)	10
α_T : transverse dispersivity (m)	1.0
α_v : vertical dispersivity (m)	0.1

5. RESULTS AND DISCUSSION

Fig. 3 shows the current simulation result for PO_4 horizontal transport at the aquifer towards the stream where the plants disposal by sludge pond exist at a distance of 300 m from the surface water stream, the sludge disposal from the fertilizer plant to the sludge pond of 7200 m^3/day where phosphate concentration of 5.5 mg/l (Wesal, 2011).

It is clear that the PO_4 will reach to the surface water stream in the flow direction with concentration line value of 2.5 mg/l. According to the standard limits for PO_4 concentration, this value exceeds 0.4 mg/l with high levels that means the current state of disposal by sludge pond with this distance from stream and disposal rates is not safe for future environmental surface water protection and



remediation.

Fig. 3. Extent of PO_4 transport towards the stream through the aquifer with sludge pond disposal system.

Figs. 4, 5 and 6 show the vertical and horizontal current simulation results for PO_4 pollutant transport at the aquifer towards the stream in a vertical section through the aquifer for the same above conditions for three different times since starting of the disposal discharge to the pond.

It shows that the PO_4 requires 30 days to reach to the surface water stream with a concentration value of 2.5 mg/l at the current state conditions of discharge, source concentrations, and pond total distance from the stream.

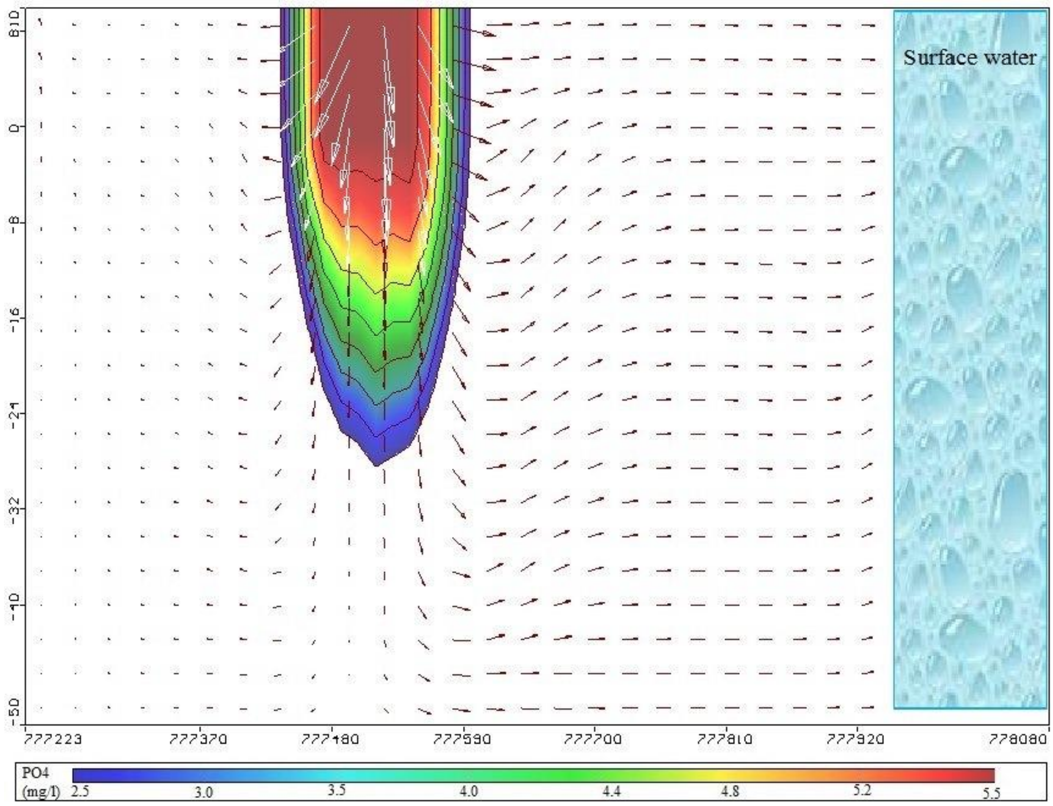


Fig. 4. Extent of PO_4 transport and flow from the sludge pond through the aquifer towards the stream after 10 days from starting of sludge disposal source.

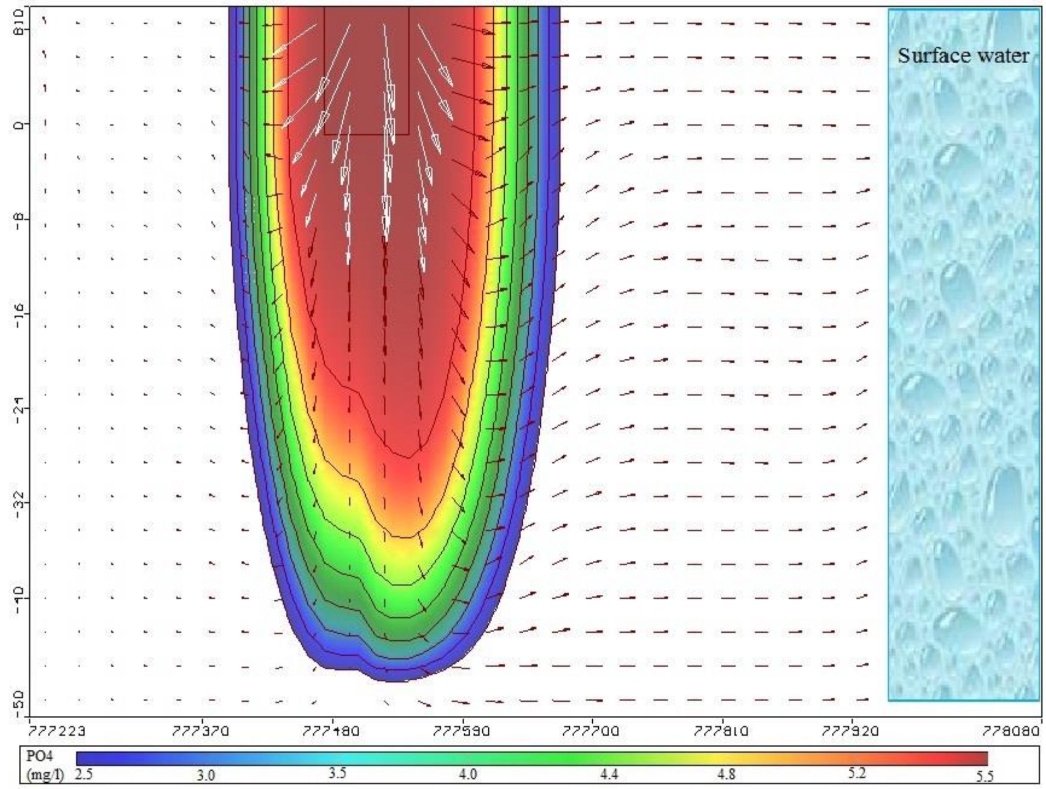


Fig. 5. Extent of PO_4 transport and flow from the sludge pond through the aquifer towards the stream after 20 days from starting of sludge disposal source.

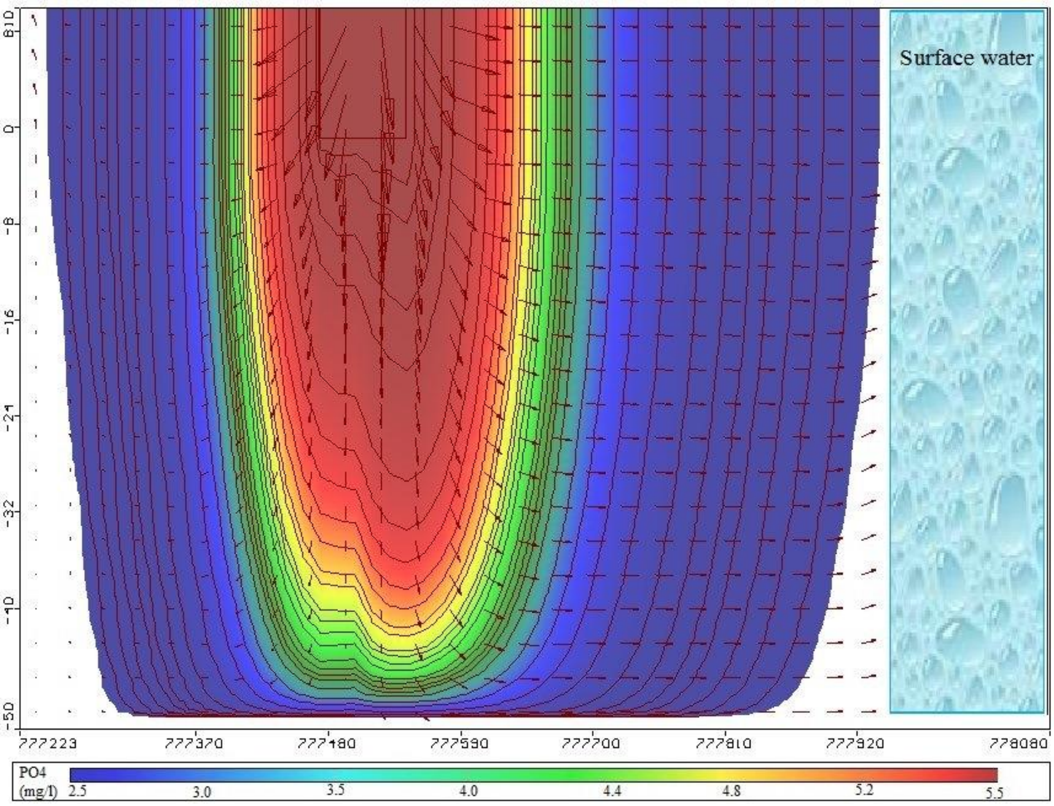


Fig. 6. Extent of PO_4 transport and flow from the sludge pond through the aquifer towards the stream after 30 days from starting of sludge disposal source.

The researcher was simulated and tested different scenarios with various injection discharges and distances from the stream to get the best conditions for controlling the pollution towards the surface water stream.

Fig. 7 shows the relationship between the injection wells discharges and total wells distances from surface water stream for controlling the source pollutants (PO_4) concentration of 5.5 mg/l reaching to the stream with a value not more than standards limits of 0.4 mg/l at dry seasons.

The best proposed system for the fertilizer plant disposal was by two injection wells with a horizontal distance of 480 m from the surface water stream, well depth should not be less than 30 m, injection rate should not be more than 3600 m^3/day for each well, and horizontal distance more than 350 m between the wells. These two wells injection proposals were proposed (for a source of PO_4 of concentration not more than 5.5 mg/l) to control the PO_4 reaching the stream with a concentration value not more than the maximum limit of 0.4 mg/l.

Fig. 8 shows the simulation result for PO_4 pollutant horizontal transport at the aquifer towards the stream for one injection well at the proposed injection wells system with above proposed conditions.

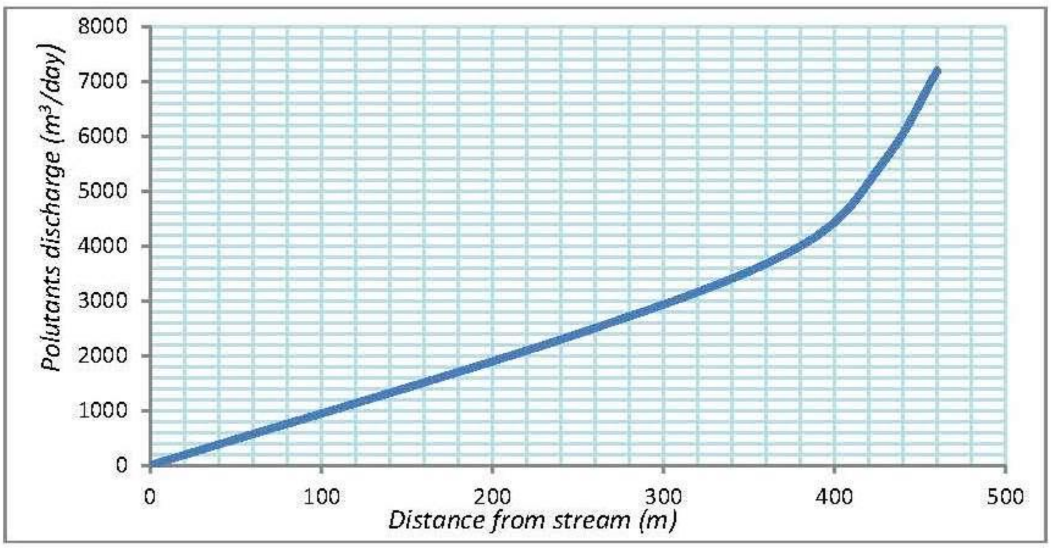


Fig. 7. Relationship between the injection wells discharges and wells distance from the surface water stream to control the PO_4 value not more than standards limits of 0.4 mg/l at the stream.

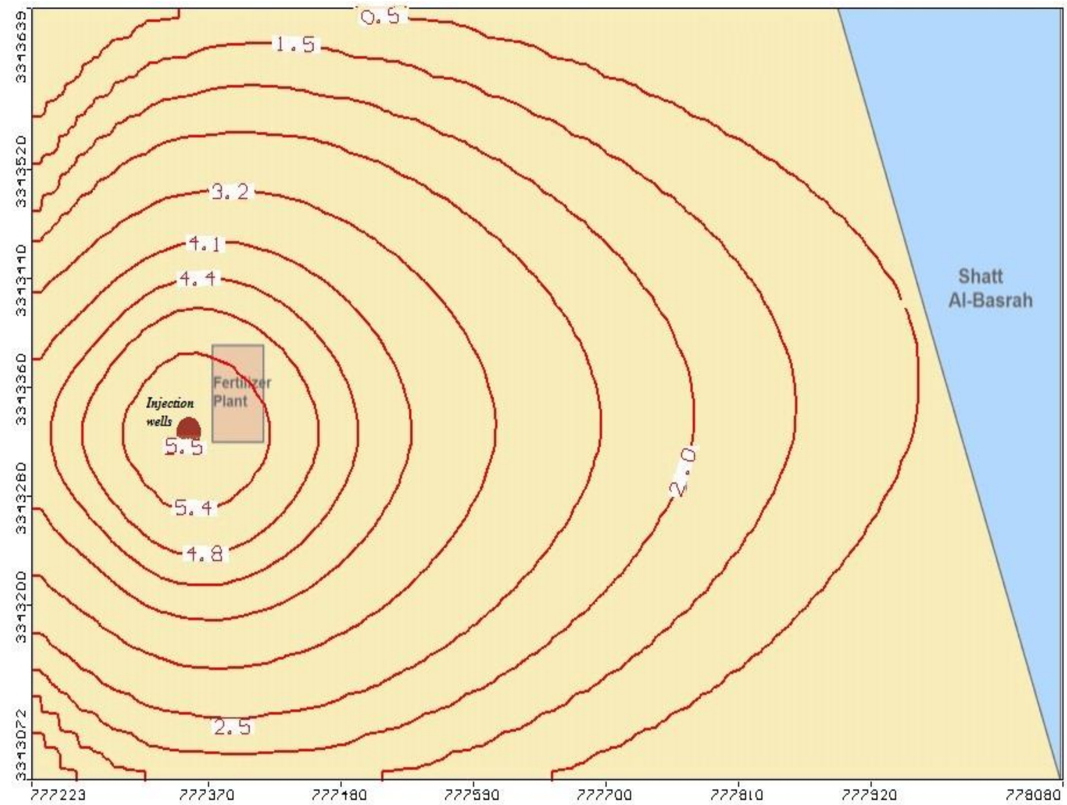


Fig. 8. Extent of PO_4 transport towards the stream through the aquifer with proposed injection well disposal system.

The PO_4 will reach the surface water stream towards the flow direction with concentration line value of 0.5-0.4 mg/l, where this system of disposal by injection wells with this distance from stream and disposal rates will be safe for the future environmental surface water protection and remediation.

6. CONCLUSIONS

The fertilizer plant disposals were a constant source of pollution. The analyses and simulation data indicated that the plant disposals act as a point source for most of Shatt Al-Basrah contaminants in that region because all the percolated wastewater and groundwater flow are towards Shatt Al-Basrah stream. The concentrations of pollutants were decreased when moved away from the disposal source along the underground flow. The pollution concentration was varied with distance away from the plant disposal. It's clear that the pollution concentration levels have increased with source concentrations and time and decreased with distance away from landfill towards the flow direction. The analyzing and simulation data indicated also that the current way of disposal by the sludge pond with this distance discharge is environmentally not safe.

A proposed disposal system was suggested in order to minimize contamination risk in the surface water and it is verified by the simulations. This approach depends on injection wells to reduce the contamination transports by aquifer soil and natural filtrations. The final solutions showed that the best disposal system is by two injection wells with an injection rate of 3600 m^3/day for each one with an approximate distance of 480 m from the surface water.

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