CONTAMINANT REMOVALS USING WASTEWATER RECHARGE

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ABSTRACT

The spreading of treated wastewaters over land as a means of disposal is a common practice in many parts of the Kingdom. This could lead to contamination of the porous media and associated health problems. Recharging of aquifers with treated wastewater, under controlled conditions, not only helps to alleviate this problem but also helps to enhance the water supply in the Kingdom.

In an ongoing study in the department of Civil Engineering, the preliminary results seem to indicate that good removal of contaminants can be achieved using local porous media and local effluents. Results show that the head loss development rate was greater when using unchlorinated effluent than that with chlorinated effluent. There was also an early development of anoxic conditions with unchlorinated effluent.

KEYWORDS

Contaminant removal, wastewater, reuse, recharge, preliminary study, dissolved oxygen.

INTRODUCTION

The massive urbanization that the Kingdom has undergone in the last 2 decades is reflected in the increase in the domestic demand for water. The Ministry of Planning in the sixth development plan (Sixth Development Plan, 1994) puts the water demand in 1994 for municipal and industrial purposes at 1800 million cubic meters (MCM). This is projected to grow to 2800 MCM by the year 1999. A large portion of this water returns as wastewater to the Kingdom's various wastewater treatment plants. Here, it is treated at some expense and then is discharged into the ocean or into the desert. Of the estimated 1000 MCM of wastewater generated in the Kingdom, only 150 MCM is reused, the rest is discharged as stated before. The volume of wastewater generated is expected to grow to 1500 MCM/yr by the year 2000.

This uncontrolled discharge of wastewaters in the aforementioned methods is not without consequences. It could be detrimental to the environment and could lead to degradation of groundwater quality. A concern associated with the disposal of treated or untreated sewage on or below the land surface revolves around the question of how far and how fast pathogenic bacteria and viruses can move in subsurface flow systems (Freeze and Cherry, 1979). Wellings et al. (1975) demonstrated vertical and lateral movement of viruses in secondary effluent discharged into a cypress dome. Viruses were shown to migrate 7-38 m laterally from the application point and to survive at least a period of 28 days.

Thus, it is clear that an environment friendly approach is needed to dispose treated wastewaters generated in the Kingdom. One promising technique is wastewater recharge. Wastewater recharge is the controlled recharge of aquifers using wastewaters. The process of recharge also results in the removal of contaminants from the wastewaters. This recharged water could be used to supplement the current water resources of the Kingdom as it can be used for irrigation. Thus, wastewater recharge would not only provide an environment friendly means for disposal of treated wastewaters, it would also contribute to the increased reuse of wastewaters. The increased reuse of wastewaters is a goal of the sixth development plan (1994) which envisages that of the total water demand (municipal, industrial and agricultural) of 17500 MCM, 310 MCM will be met by treated wastewaters.

Wastewater recharge offers several advantages. It is more economical to recharge and use the recharged water than to use water from other sources such as desalination or other traditional tertiary treatment techniques. Other than that, the aquifers into which the wastewater is recharged can serve as multi-year reservoirs. Underground reservoirs are ideal storage facilities in desert type climates where evaporation rates are high. The use of reclaimed wastewater for agriculture may lead to a reduction in the commercial fertilizers applied. This is due to the presence of nitrogen and phosphorous compounds in the reclaimed water (Moore et al., 1985). It is a supply source that is secure even during times of drought (Guymon and Hromadka, 1985).

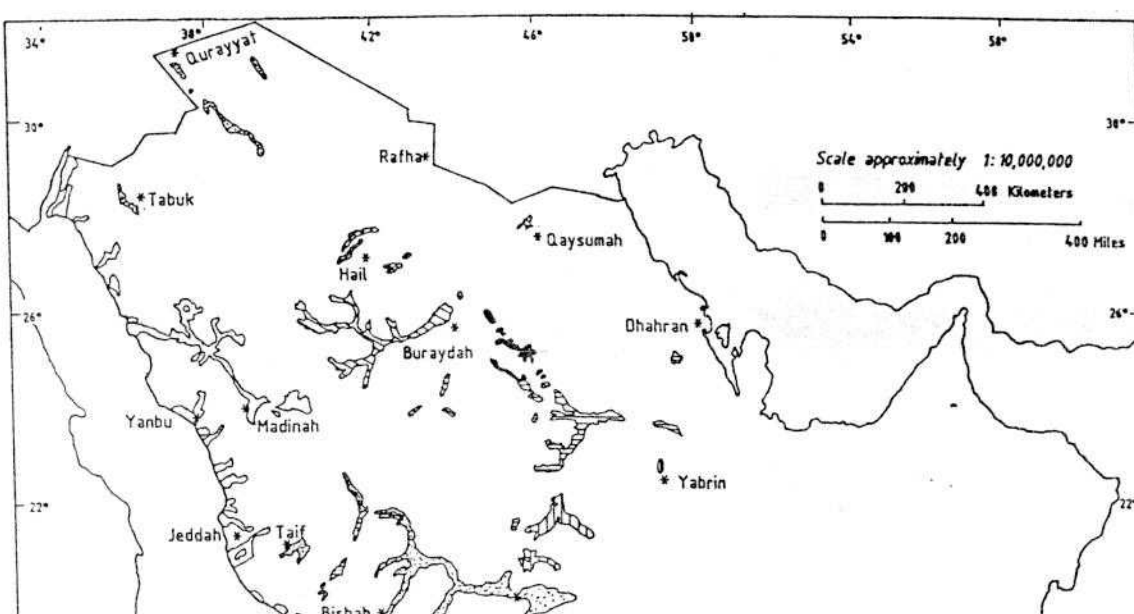
RECHARGE METHODS AND RECHARGE SITES

Treated wastewater can be recharged either through injection wells or through spreading basins. Spreading basins are frequently used and it involves the surface spreading of water in spreading basins or recharge basins. Recharge wells or injection wells are used to directly recharge water into deep water-bearing zones and for confined aquifers, injection/recharge wells are the only alternative (Zikmund and Cole, 1996). Where land is scarce and large areas for spreading cannot be made available, recharge wells are advantageous. Though there are numerous cases of recharge wells being used for secondary wastewater recharge, spreading basins present fewer problems from the point of view of clogging, and the maintenance is cheaper.

Desert soils in the Kingdom have high infiltration and percolation rates, making them quite suitable for spreading basins. Surface spreading is most effective where there are no impending layers between the land surface and the aquifer, thus alluvial aquifers and the outcrops of principal aquifers would be ideal sites for spreading operations.

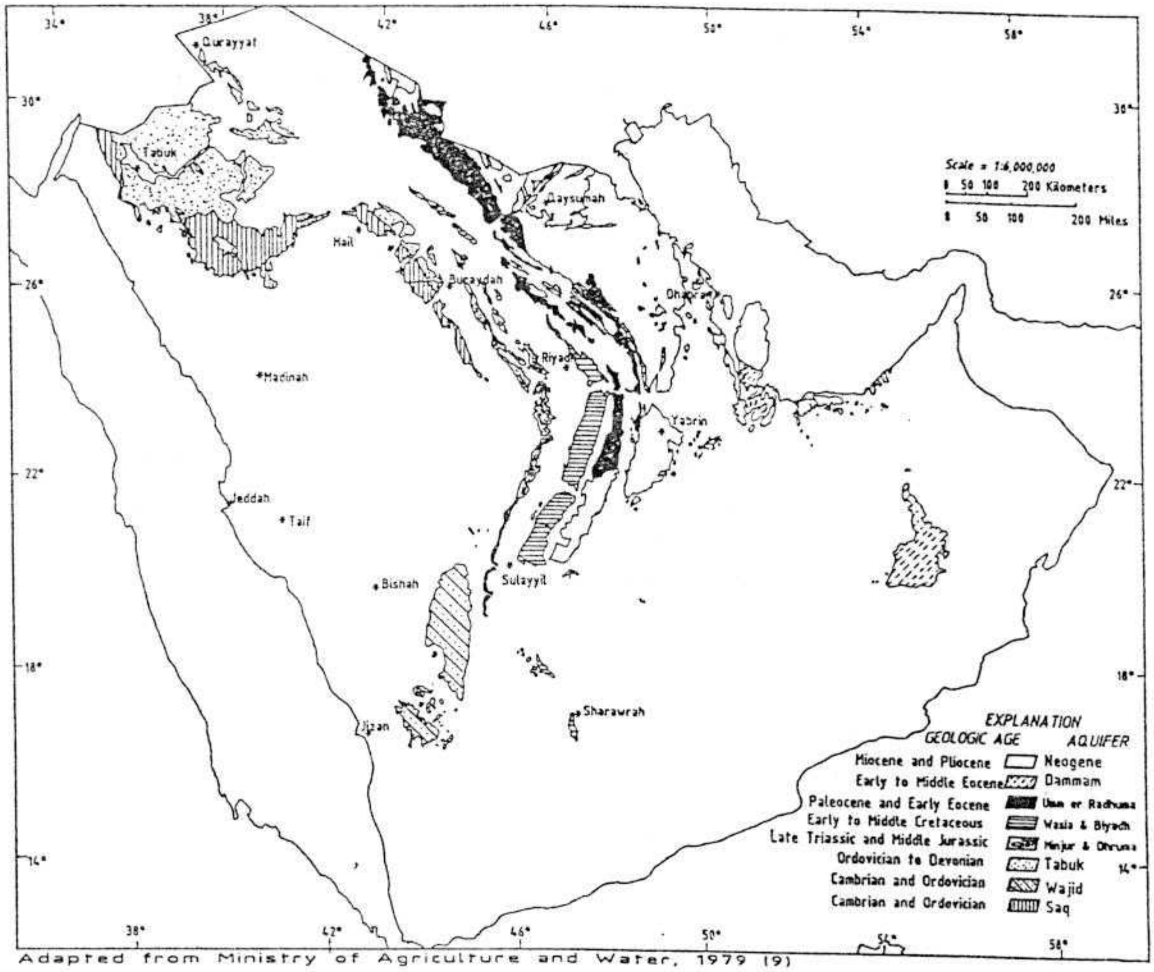
Fig. 1 (Ministry of Agriculture and Water, 1979) shows the alluvial aquifers in the Kingdom. The alluvial deposits fill many drainage areas on the western coastal plains of the Kingdom. The aquifers are generally unconfined but may be semi-confined or confined at some places. The transmissivity generally varies from 102 and 104 square meter per day (Water Atlas of Saudi Arabia, 1984).

Fig. 2 (Ministry of Agriculture and Water, 1979) shows the outcrops of the principal aquifers. The Kingdom's principal aquifers provide a dependable supply of water for most parts of central and eastern Saudi Arabia. They range in geologic age from Cambrian to Tertiary (Water Atlas of Saudi Arabia, 1984).



Adapted from Ministry of Agriculture and Water, 1979 (9)

Fig. 1. Location of areas where alluvial deposits are water bearing



Adapted from Ministry of Agriculture and Water, 1979 (9)

Fig. 2. Outcrop areas of principal aquifers

WATER QUALITY TRANSFORMATIONS

As wastewater percolates through the porous matrix of the soil, its quality undergoes transformations. Transformations in the recharge water quality are the result of one or more of the following (Roberts, 1980):

1. biodegradation by and growth of microorganisms
2. chemical oxidation reduction
3. sorption and ion exchange
4. filtration
5. chemical precipitation or dilution
6. volatilization or photochemical reactions (in spreading basins).

The transformations are site specific and to obtain optimum contaminant removal, land treatment systems must be carefully designed. The change in the water quality has been monitored in many wastewater recharge projects and have been widely reported (Bouwer et al., 1984; Carre and Dufils, 1991; Buros, 1976). The potential for contaminant removal by wastewater recharge operations have been aptly summarized by Culp et al. (1979) as shown in Table 1. Most reclaimed water contaminants are substantially removed during vertical percolation through soil and during horizontal movement in the aquifers. Notable exceptions are total dissolved solids, hardness, nitrates, and a few heavy metals. Though equally good removals can be expected in the Kingdom, the exact removals for various sites in the Kingdom would have to be determined through field studies. However, given the vast number of uncertainties involved in field scale wastewater recharge projects, there exists a great need to precede such projects by laboratory studies.

Table 1. Potential for contaminant removal by wastewater recharge operation (Culp et al., 1979)

Constituent	Removal potential (Percentage of influent concentration)
BOD	>50
COD	>50
NH_3-N	>50
NO_3-N	
Phosphorus	>50
Alkalinity	25-50
Oil & grease	>50
Total coliform	>50
TDS	
Arsenic	
Barium	
Cadmium	25
Chromium	
Copper	>50
Fluoride	25-50
Iron	
Lead	25-50
Manganese	
Mercury	
Selenium	
Silver	
Zinc	>50
Color	>50
Foaming	>50
Turbidity	>50
TOC	>50

*The blank spaces denote no data, inconclusive results or an increase.

LABORATORY STUDY

A preliminary laboratory investigation was conducted to compare the effect of chlorinated and unchlorinated effluents on clogging time and to establish a conservative estimate of the contaminant removals that can be obtained by the recharge of local effluents through a sand dune. For the latter, the study was conducted under conditions that minimised the removal of pollutants i.e. under saturated flow conditions and high effective velocity. In particular, the development of anoxic conditions was studied.

For the preliminary study, a vertical circular Plexiglas column (Fig. 3) of internal diameter 0.203 m and a length of 2.41 m was used. The column had sampling ports along its length, the middle port being at a distance of 1.25 m from the bottom. For determining the spatial distribution of pressure, there were 7 piezometers ports at approximately equal spacing along its length. The distances from the top of the sand to the piezometers 1 to 7 were 0.10, 0.40, 0.71, 1.01, 1.32, 1.62, and 1.92 m, respectively. This column was fitted with a perforated pipe at the top to create a shower effect so as to allow a uniform distribution throughout the width of the column. At the bottom, the outlet was connected to a drain through a plastic pipe of 0.75 inch internal diameter. This pipe could be raised to different levels to control the final effective head. A hole was made at the point 1 to prevent siphon action from taking place.

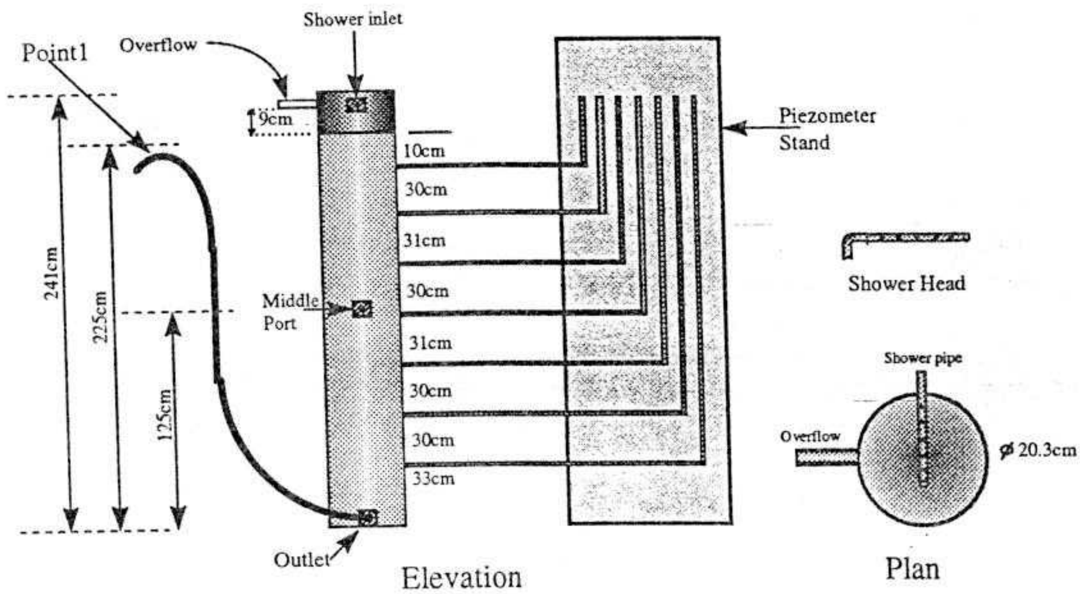


Fig. 3. Column for preliminary studies

This column was filled with 90 kg of sand using the pluviation technique, creating a sand column of height 2.25 m. The height of the pluviation was 1.25 m and the resulting density in the column was 1235 kg per cubic meter. Water was pumped from a storage sump through a 0.25 hp pump into the column and the flow was controlled by a valve. A constant head was maintained in the column by providing an overflow outlet at the top of the column just below the shower arrangement. The flow was adjusted to ensure a slight overflow always. This experimental setup is shown in Fig. 4.

There were two experiments in this category. The first run using unchlorinated effluent is labeled Experiment PUC (Preliminary run, Unchlorinated). The second run using chlorinated effluent is labeled Experiment PC (Preliminary run, Chlorinated).

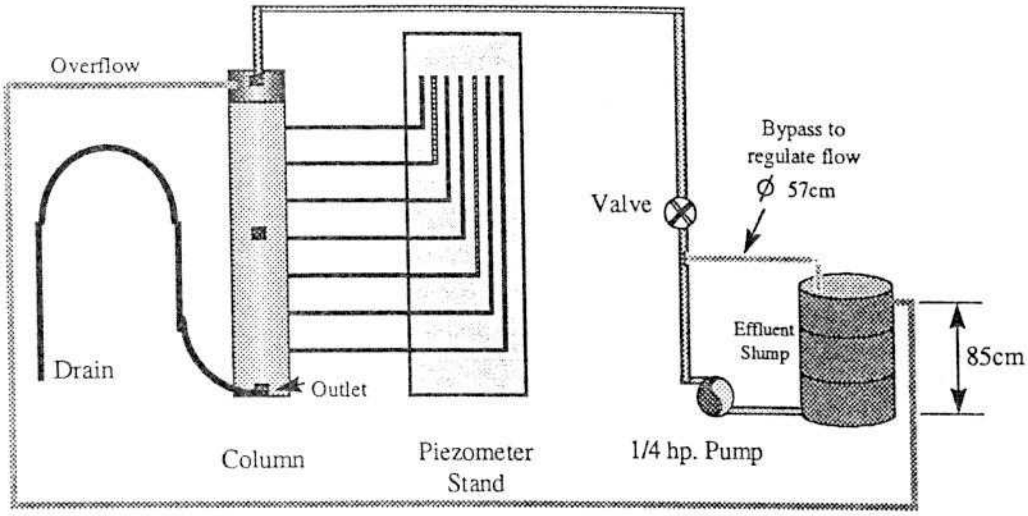


Fig. 4. Setup for preliminary studies

Experiment PUC

In Exp. PUC, unchlorinated effluent was introduced into the preliminary study Plexiglas column on a continuous basis. The effective head was 58 cm, giving a darcy velocity of 0.31 cm/min. With an effective porosity of 0.3, the effective velocity in this experiment was 1 cm/min. Samples were withdrawn at the middle of the column (100 cm from top of sand column) and at the exit point (225 cm from top of sand column). These were analysed for pH, Conductivity, Turbidity, Dissolved Oxygen, Total Organic Carbon (TOC), and Total Coliform (TC) on a daily basis. The outflow at the exit was also measured on a daily basis and so was the piezometric head at all 7 ports.

Experiment PC

In Exp. PC, chlorinated effluent was introduced into the preliminary study Plexiglas column on a continuous basis after the column had been filled with fresh sand weighing approximately 90 kg. Other operating conditions were the same as for Exp. PUC.

Results show that the head loss development rate was greater when using unchlorinated effluent than that with chlorinated effluent. After 197.5 hrs of operation in PC, the head loss at all ports was less than the head loss after 190 hrs of operation for PUC. The rate of clogging is greater in the experiment using unchlorinated effluent because in the experiment using chlorinated effluent, the presence of chlorine in the water restricted the growth of bacteria and algae.

The main and the most significant difference in the performance of chlorinated and unchlorinated effluents was in the development of anoxic conditions. After 197.5 hrs of operation, the dissolved oxygen (DO) levels still had not reached anoxic levels at both the middle and the bottom of the column with chlorinated effluent (Fig. 5). However, the development of anoxic conditions occurred within 165.5 hrs in the column using

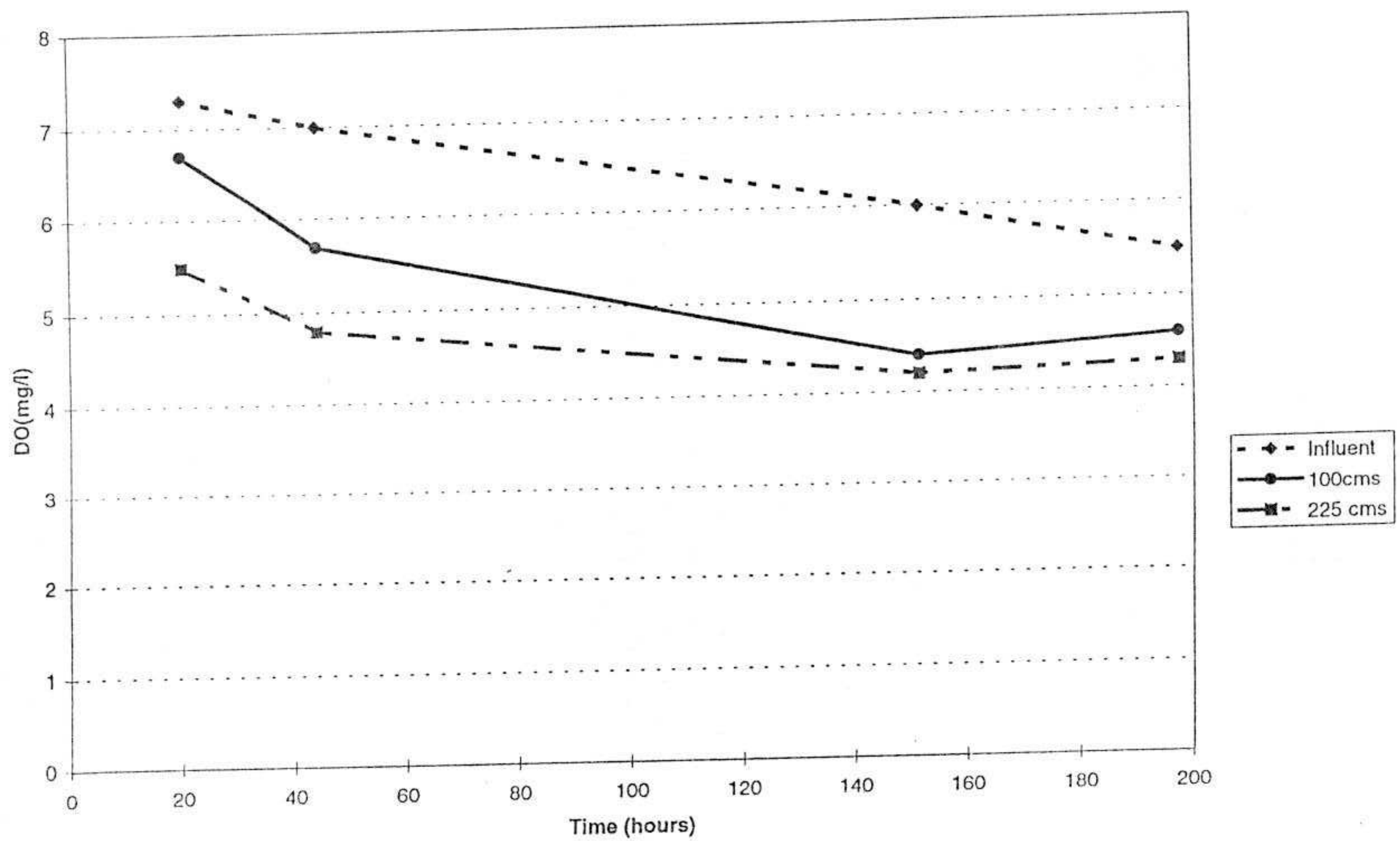


Fig. 5. Dissolved oxygen concentration at various depths during Experiment PC

unchlorinated effluent (Fig. 6). Thus, to avoid the development of anoxic conditions in the aquifer, chlorinated effluent is to be preferred to unchlorinated effluent.

Using unchlorinated effluent, the average percentage removals of suspended solids (SS), Total Organic Carbon (TOC), and Total Coliform (TC) were 34.4, 25 and 83.75, respectively. Using chlorinated effluent, the average percentage removals of SS, TOC and TC were 57.3, 34.5 and 65.22, respectively. The product water turbidity was consistently less than 0.5 NTU.

SUMMARY AND CONCLUSIONS

The treated wastewaters generated in the Kingdom need to be disposed in a more environment friendly manner. One promising technique is wastewater recharge. The removal of contaminants from the recharged water would allow it to be used to supplement the current water resources in the Kingdom.

A laboratory investigation was conducted to compare the effect of chlorinated and unchlorinated effluents on clogging time and to establish a conservative estimate of the contaminant removals that can be obtained by the recharge of local effluents through a sand dune.

Results show that the head loss development rate was greater when using unchlorinated effluent than that with chlorinated effluent. There was also an early development of anoxic conditions with unchlorinated effluent. Thus, the use of chlorinated effluent gives the added advantage of longer recharge periods without the development of anoxic conditions.

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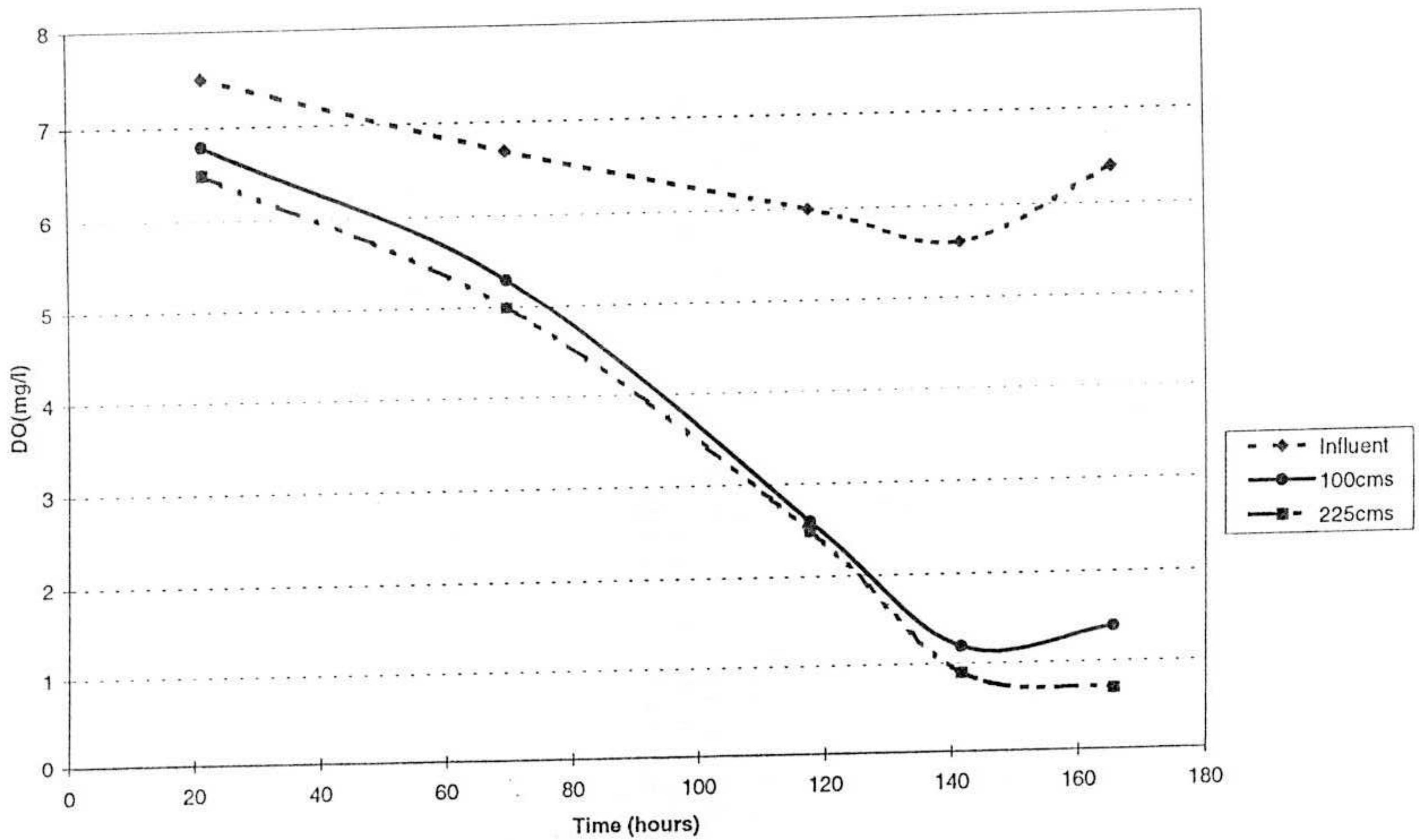

Fig. 6. Dissolved oxygen concentration at various depths during Experiment PUC

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