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Feasibility of long-term irrigation as a treatment method for municipal wastewater using natural soil in Kuwait

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ABSTRACT

Passing treated wastewater through soil is a natural and economic means to improve the quality of wastewater. The United Agricultural Production Company (UAPCO) farm located in the Sulaibiya area of Kuwait has been irrigated with tertiary treated wastewater since 1976. A field investigation at the farm has been conducted by the Kuwait Institute for Scientific Research (KISR) to assess the applicability of the natural soil treatment method, in the long term, to improve the quality of the treated wastewater under the conditions prevailing in Kuwait. The collected data have been analyzed to assess the degree of improvement in quality of the infiltrated water with respect to the tertiary wastewater used for irrigation. The data analysis indicates that in spite of low clay content of the soil, improvement in the quality of the tertiary treated wastewater through soil aquifer treatment by the removal of ammonia (>90%), iron (>80%), organic carbon (>90%), biological oxygen demand (BOD) (100%) and bacteria (50–100%, depending on its type), can be expected over a long-term period. Soil leaching, however, tends to increase the total dissolved solids of the infiltrated water and the nitrification process increases the nitrate content.

1. Introduction

1.1. Background

As the sources for supply of freshwater are either becoming scarcer or polluted through human intervention, the reuse of municipal wastewater is becoming an important issue in the world with increasing demand for water for human consumption and agriculture. The matter is rather acute in arid and semiarid countries such as Kuwait, where the sources of freshwater are very limited. In Kuwait, as in the other Gulf Cooperation Council (GCC) countries, desalination plants meet the bulk of the freshwater demand. With the rapidly rising demand for freshwater and the high cost of installation and maintenance of the desalination plants, the situation is getting more and more critical. Treated wastewater can be an important source of useable water, especially for agriculture. The volume of generated municipal wastewater will be increased in the future with increases in consumption and the treatment capacity will also be increased to keep pace with it. It has been estimated that in Kuwait, the daily production of treated municipal wastewater will reach 635,600 m^3/d by the year 2015 (Al-Otaibi et al., 2001). Utilization of this resource is a high priority for the water managers of the country. Soil aquifer treatment (SAT) is a low cost process for the improvement of the quality of the wastewater as it infiltrates through the soil. Field trials have taken place to demonstrate the applicability of the SAT technique to improve the quality of treated wastewater in Kuwait (Al-Otaibi et al., 2001). Table 1 presents a summary of these results. This table indicates that SAT process performed very well in the Sulaibiya area of Kuwait, at least, in the short term with respect to parameters like chemical oxygen demand (COD), biological oxygen demand (BOD), ammonia (NH_3), phosphates (PO_4) and bacteria

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Table 1 – Wastewater quality before and after SAT in the Sulaibiya area, Kuwait (Al-Otaibi et al., 2001)

Parameter	Tertiary treated wastewater (before SAT)	Water from monitoring wells (after SAT)	Removal by SAT (%)
pH	6.5	7.8	–
TSS (mg/L)	2	5	−150
COD (mg/L)	21	2	90
BOD (mg/L)	3	0.1	97
TDS (mg/L)	1056	1874	−77
Ammonia (mg/L)	6	0	100
Nitrates (mg/L)	5	2	60
Phosphates (mg/L)	10	0.1	99
Turbidity	5	3	40
Coliform bacteria (cfu/100 mL)	200	0	100

TSS = total suspended solids; COD = chemical oxygen demand; BOD = biochemical oxygen demand; TDS = total dissolved solids; cfu = colony forming units.

(with coliform bacteria acting as an index). The increase in total dissolved solids (TDS) was attributed to the leaching of soluble materials like carbonates and sulfates from the unsaturated zone during the infiltration of irrigation water to the water table. It was concluded from the study that the technique is capable of improving the quality of the treated wastewater to the extent that the SAT-treated water can be used for irrigation with slight to moderate restriction (FAO, 1985) and for other non-potable purposes.

1.2. *Previous studies in Kuwait*

The applicability of the SAT process in Kuwait has been under investigation for several years. Soil column tests in the laboratory were conducted by Al-Awadi and Rashid (1999) to investigate improvement in the quality of treated wastewater as it infiltrated through the columns. Six columns were set up in the laboratory using soils from the Sulaibiya, Riggae and Jahra areas to represent different soil types. Tertiary treated wastewater (after passing through a settlement tank, primary clarifier, activated sludge process or trickling filter, secondary clarifier and chlorination) from the Data Monitoring Center (DMC) was used as the recharge water. The study concluded that:

- Under steady operating conditions, significant improvement in the quality of tertiary treated (after chlorination) wastewater could be achieved through soil treatment.
- Based on various operational criteria, the Sulaibiya area was found to be the most suitable site for implementation of a pilot-scale project for the improvement of wastewater through soil treatment.

Field experiments to explore the feasibility of SAT for the renovation of wastewater under the conditions of Kuwait were conducted through a set of seven ponds at a site next to the DMC (Fig. 1) with treated wastewater supplied from the DMC (Al-Otaibi et al., 2001). Initially, infiltration rates through the infiltration ponds were very low due to the low vertical permeability of the soil at the study site in Sulaibiya. Drilling a total of 10 holes, 250 mm in diameter, in one of the infiltration ponds and filling them with 5-mm gravel improved the infiltration rates. The maximum infiltration rate achieved in this pond was about 10 cm/d as compared with the 3 cm/d achieved in other ponds. The final results showed that:

- Except for the nitrate contents, improvement in quality was very good (Table 1). Evapotranspiration and dissolution of the materials in the unsaturated zone may be partially responsible for somewhat high TDS levels in the infiltrated water, which in turn, affected the TDS of water recovered from the monitoring well near the study site.
- The wastewater, after treatment, could be used for unrestricted irrigation.
- Nitrate removal needed improvement through creation of anaerobic zones in the unsaturated region of the aquifer. Wet and dry cycles might be alternated to remove nitrogen by anaerobic ammonia oxidation as was done in Tucson, Arizona (Light, 1994).

Al-Haddad et al. (2003) observed that the SAT process completely removed pyrene (a polycyclic aromatic hydrocarbon) from the treated wastewater (initial content in the range of 15–30 mg/L) in the Sulaibiya treatment site in Kuwait. Organic carbon, aromatic hydrocarbons and petroleum hydrocarbons were also removed from the tertiary treated wastewater.

Field investigations were carried out to assess the thickness of the percolated treated wastewater below the SAT system at the Sulaibiya treatment site from the vertical and lateral distribution of nitrate levels in the groundwater system (Al-Qallaf and Al-Salman, 2004). The study showed that the percolated treated wastewater formed a conical plume below the SAT system with a diameter of about 50 m at the water table and a diameter of about 10 m at a depth of 10 m below the water table.

Overall, the studies carried out in Kuwait so far have indicated that it should be possible to bring improvement in the quality of the tertiary treated wastewater through the SAT process.

1.3. *Objective of the current study*

The current study was planned to provide information on long-term (almost 30 years) effects of irrigation of an agricultural farm with treated wastewater on the groundwater table and groundwater quality under the soil and meteor-