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WASTEWATER SUBSURFACE INFILTRATION-PERCOLATION TECHNIQUE FOR WATER RECYCLING

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Abstract

Artificial recharge of groundwater with treated wastewater is gaining wide acceptance as a method to replenish over-drafted aquifers and provide sustainable water supplies. In spite of the apparent simplicity, the artificial recharge technique using natural soil/sediment as a reactor for treatment must be rigorously defined. In this paper, we give hydrogeological characterization of soil and underlying sediments distributed at the site of pilot plant for treated wastewater infiltration-percolation based on drilling survey. The hydrogeological parameters obtained from present study ensure an adequate performance of the pilot plant for infiltration-percolation of treated wastewater and the annual loading rate is estimated.

Keywords : Geopurification, Wastewater reuse, Infiltration-percoration, Hydrogeology, Annual loading rate

A gigantic effort has been deployed in the matter of water resources management and wastewater treatment. It is required to reach two complementary purposes: provide to Tunisians sufficient water in terms of quantity and quality, meet the increase of the demand and safeguard the existent reserves. The intensive tourist activities, the over exploitation of coastal aquifers by the farmers and the demographic increase, are so many factors which hang over the Mediterranean coast. In this sensible medium, a pronounced saline intrusion in coastal aquifers, took place and continue to progress nowadays. At another hand, we assist to a marine degradation by the discharge of poor quality treated wastewater, especially at overloading periods. An integrated water management including wastewater reuse became a necessity to assure a sustainable development and perpetuity of the different economic activities on the littoral areas: tourism, fishing, fish farming, agriculture, etc. The main challenge is to reach a zero discharge of treated wastewater to the sea in order to benefit the farmers with another water resource and avoid coastal waters pollution. For this purpose, we have to disinfect wastewater at a tertiary level to meet the non-restrictive irrigation standards. Instead of use of costly disinfection techniques (chlorination, UV disinfection, etc.), use of the infiltration-percolation (IP) or rapid infiltration (RI) - increasingly called soil-aquifer treatment systems (SAT) - on the border dunes or river sides in order to recharge aquifers, seems to be more simple and economic. This solution gives the opportunity to farmers to dispose of water with a better quality, which could be used in non-restrictive irrigation and drip systems without problems of failure.

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These techniques which use soil as a reactor for treatment, are usually rudimentary but evolve to a more elaborated forms while conserving an affirmed rustic character. However, in spite of their apparent simplicity, they must be rigorously defined. In this paper we present the results of borehole drilling survey and indoor permeability test of the subsurface soil/sediments that are expected to be used as a reactor for infiltration-percolation process.

The Nabeul area, Mediterranean coast in Tunisia, has been chosen for the pilot study site for treated wastewater infiltration-percolation. We give hydrogeological characterization of soil and underlying sediments distributed at the site based on drilling survey. In the site, it can be divided into two geological units, unconsolidated sand to gravel layers (0-13.8m in depth) and consolidated silt to clay beds (below 13.8m in depth). The former unit most probably corresponds to the Quaternary while the later can be correlated with Tertiary (Miocene) marine formation. The level of natural groundwater table at summer season (July 2001) is observed around 10m in depth. The upper unconsolidated sand to gravel layers are the porous media for groundwater circulation, and the lower consolidated silt to clay beds play a role of hydrogeological basement. The permeability varies from 10^{-4} to 10^{-6} m/sec. for upper unit while less than 10^{-9} m/sec for underlying silt to clay beds.

The results indicate that the vadose zone vary since the river bed to the basin site from 10 to 13 m, the aquifer thickness 2 to 3 m and the aquifer permeability estimation based on granulometry 10^{-4} to 10^{-5} m/sec. Determining the design annual hydraulic loading rate is one of the most critical aspects of RI system design. The hydraulic loading rate is based directly upon the field and laboratory test results for infiltration and permeability.

If the site investigation reveals a specific layer that will restrict flow, the design is based on the permeability of that layer regardless of its thickness (usepa, 1981). In our case the lowest value for the vadose zone and the aquifer reservoir permeabilities, is 5.4×10^{-5} m/sec (according to the Constant Level (CL) method). This value (19.4 cm/h) defines the amount of clean water that can move through a unit cross-section in the soil, at unit gradient and under saturated conditions. Thus, Clean water rate, L_{cw} is given by :

$$L_{cw} = (19.4\ \text{cm/h})(24\text{h/d})(365\text{d/yr})(1\text{m}^2)/\ (100\text{cm/m})$$
$$= 1699.4\ \text{m}^3/\text{yr}$$

The loading can also be expressed in terms of a depth of water on a unit area because of the dimensions involved, so:

$$L_{cw} = (1699.4\ \text{m}^3/\text{yr}) / 1\ \text{m}^2 = 1699.4\ \text{m/yr}$$

However, most of the commonly used test procedures require the adjustments (safety factors) regarding that wastewater will be used for infiltration. This factor is estimated by usepa, 1981 upon full scale systems which are successfully operated. For Laboratory permeability measurements, this factor is 4-10% of restricting soil layer permeability. Thus, annual wastewater loading, L_{ww}, is given by :

$$L_{ww} = (0.04)(\text{clean water rate, } L_{cw})$$
$$=(0.04)(1699.4) = 68\text{m/yr}$$

Determination of the annual loading rate is in effect a definition of the capacity of the site to transmit wastewater if applied at some undefined, but regular schedule throughout the year. But in the case of Wadi Souhil system, operation is limited to winter because there is no demand for the irrigation area. For that, we have to reduce the annual loading proportionally to account for the non-operationg period. System operation is planned for winter period (November-March), so 6 months per year :

$$L_{ww} = (6/12)(68\text{m/yr}) = 34\ \text{m/yr}$$

With this study, we defined the most important parameter for system design, but it remains another important parameter for system operating is the Wet/Dry ratio. Indeed, a regular drying period is essential for the successful performance of RI systems. The period required for drying is a function of the solids and degradable organics in the wastewater and of the climatic influences on aerobic reactions. The ratio of loading to drying periods within a single cycle for successful systems varies, but is almost always less than 1. In order to determine this ratio, we will conduct some experiments on columns reproducing the site layers and operated with different Wet/Dry ratios.

In spite of the apparent simplicity, the artificial recharge technique using natural soil/sediment as a reactor for treatment must be rigorously defined. The hydrogeological parameters obtained from present study ensure an adequate performance of the pilot plant for infiltration-percolation of treated wastewater and the annual loading rate.