

Cost-efficient management of coastal aquifers by recharging with treated wastewater

Abstract

Seawater intrusion (SWI) is a special category of hydro-environmental problems, threatening water resources in coastal areas by making groundwater resources unsuitable for human, industrial and irrigation uses. Therefore, efficient management strategies should be applied in coastal aquifers to mitigate the impacts of SWI problems. The present paper gives a view about the application of treated wastewater (TWW) in artificial recharge of coastal aquifers against SWI. Application of reclaimed water for common utility sectors and/or artificial storage in subsurface layers can help to satisfy part of the water demand, help with management of flooding and drought and protect against SWI.

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Introduction

In coastal areas and under natural conditions, the seawater with higher density displaces the deep inland freshwater. This SWI process is intensified by unplanned abstraction of groundwater and consequently results in degradation of the quality of the groundwater. This could in turn lead to abandonment of abstraction wells of freshwater, human health problems, damage to natural ecosystem and damage to agricultural farms by reducing yields and damaging crops.¹ Thus, development of coastal areas in terms of water supply is limited by the SWI risks. According to Bruington,² one part of seawater containing, e.g., 35,000 mg/l of dissolved salts can degrade 33.5 parts of freshwater from 500 mg/l to 1,500 mg/l (i.e., from acceptable to non-acceptable level of salinity). Mixing of 2-3% salinity would render the fresh groundwater resources unsuitable for human consumption and slightly higher levels of mixing ($\geq 5\%$) is enough to make the aquifer unsuitable for agriculture and irrigation.¹⁻⁴ Therefore, in the face of SWI problem, appropriate management measures have to be taken to control the growing scarcity of subsurface water in coastal aquifers. A number of methods have been proposed in the literature to control SWI hydraulically. Maintaining a seaward hydraulic gradient of coastal flow regime and allowing a proportion of the freshwater to flow into the sea (submarine groundwater discharge) are the key elements in the proposed management methodologies. Artificially recharging the aquifer by high-quality water (e.g. surface water, rainwater, extracted groundwater or desalinated water) is among the widely used strategies suggested in the literature⁵⁻¹¹ to mitigate SWI problem by raising the inland piezometric heads. Artificial recharge of water can also help to reduce the flood flows, increase the water storage of aquifer, raise groundwater levels, relieve over-pumping and finally improve water quality and suppress the SWI.^{12,13}

The cost of providing high quality water and its delivery and injection in the aquifer is the main limitation to the recharge barriers. Also, access to such water is limited in many parts of arid and semi-arid regions that suffer from scarcity of water especially in dry years.¹⁴ Therefore, in our opinion more emphasis should be placed on application of reclaimed or renewable sources of water, such as treated waste water (TWW), as source of recharge to mitigate SWI.

Surface reservoirs, lakes, canals and other spreading recharge basins can be used as recharge systems to feed the unconfined aquifer systems instead of application of deep recharge wells. The collected TWW can be allowed to percolate through the unsaturated zone to the underlying aquifer. It helps to retard the saline water by increasing the seaward gradient of water heads.¹⁵ The initial costs of various schemes of artificial recharge in an alluvial area in India have been reported to be 551, 8 and 1 \$/1000m³ of recharge structure for recharge wells, spreading channel and percolation tank (pond) respectively. Also the running costs of the recharge through the same structures were 21, 20 and 1\$/1000m³/year respectively manifesting the great economic advantage of the surface recharge ponds.¹⁶⁻¹⁸ Typically, in the primary treatment process of wastewater, about 90 to 95% of settleable solids, 40 to 60% of total suspended solids (TSS) and 25 to 35% of BOD are removed. In the secondary treatment 85 and 95% of BOD and total suspended solids (TSS) are removed from raw sanitary wastewater and only 30 mg/l or less of BOD and TSS are released untreated. And finally in the tertiary wastewater treatment more than 99% of the pollutants are removed from the raw wastewater releasing almost a potable (drinkable) effluent or treated wastewater.^{19,20} Minimum nitrogen and phosphorus removal of tertiary treatment process is about 70% and 80% respectively.^{21,22} The beneficial aspects of secondary treated wastewater passed through a multi-media filtration system (final TDS = 755 mg/l), in recharging of the aquifer using surface recharge system has been shown by²³ Monitoring of the water quality of the percolated TWW in vadose zone highlighted that significant reduction in amounts of several constituents (30% reduction for phosphorous, 66% for fluoride, 62% for iron and 51% for total organic carbon) of the recycled water was achieved implying the general enhancement of the water quality obtained by recharging the TWW. This reaffirms that the TWW can be used as a reliable source for subsurface storage of the water. Shamma²⁴ used a 3D numerical model to assess the future effectiveness of the deep injection of treated water in the Salalah aquifer in Oman. The recharge system was already established and was followed in the studied area. The TWW returned from the available central sewage treatment plant with TDS of 1000 mg/l was injected into wells in a line parallel to the coast. Vandenhede et al.²⁵ used an artificial recharge system using two recharge ponds to feed the dunes of the western Belgian coastal

plain and to develop a safe and sustainable water extraction system against seawater intrusion. Tertiary TWW effluent produced from the combination of ultra-filtration and reverse osmosis (TDS=500mg/l) was used in these ponds for the recharge. Also, effects of the number and locations of artificial recharge ponds to alleviate SWI risks in Wadi Ham aquifer (UAE) were studied by Hussain et al.²⁶ using 3D numerical modelling. The collected reclaimed water (with TDS of 1300 mg/l) in artificial ponds with 100 m×100 m ×1m dimensions, was allowed to percolate into the aquifer with an average rate of 0.5 m/day. Their results showed that in comparison to the no-recharge scenario, the saline/freshwater interface could be pushed back in seaward direction by 240-550 m, which measured at different cross sections along the coast. The great potentials of TWW on control of SWI problem and enhancement of the piezometric water levels have also been highlighted by Koussis et al.²⁷ Kourakos & Mantoglou,^{28,29} Hussain et al.^{15,30} in recent years.

Conclusion

In our view, focusing on the good quality of reclaimed surface or runoff water should be more widely adopted for recharging of the aquifers especially in coastal regions. It helps to mitigate the risks of saltwater intrusion and flooding, beside its positive influence on water-balance during the water scarcity crises in drought periods of the years. Moreover, a higher level of efficiency and a long-term sustainability of the system would be guaranteed by direct collection of the reclaimed water in several surface recharge basins/ponds designed in different locations along the coastal area for recharging and feeding of the unconfined aquifer. However, further attention is required on application of this type of water in order to reduce the associated health, environmental and economic risks.

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Conflict of interest

Authors declare there is no conflict of interest in publishing the article.

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