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 aquafers 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.

Opinion

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Mohammed S Hussain[1] and Akbar A Javadi[2]*

[1]*Department of Civil Engineering, University of Duhok, Iraq*

[2]*Department of Engineering, Mathematics and Physical Sciences, University of Exeter, UK*

***Corresponding author:** Akbar A Javadi, Department of Engineering, Mathematics and Physical Sciences, University of Exeter, UK, Email: a.a.javadi@ex.ac.uk

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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 (≥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 literature [5-11] to mitigate SWI problem by raisings 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 onion 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 $/1000 m3 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\$/1000m^3/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 by Bekele et al. [23]. 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. Shammas [24] 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. Vandenbohede 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 piezometeric water levels have also been highlighted by Koussis et al. [27], Kourakos & Mantoglou [28,29], Hussain et al. [15,30] & Javadi et al. [31] 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.

Acknowledgment

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Conflict of Interest

None.

References

1. Sherif MM, Singh VP (1996) Saltwater intrusion. In: Singh V (Ed.), Hydrology of Disasters. Springer, Netherlands.
2. Bruington AE (1972) Saltwater Intrusion into Aquifers[1]. Jawra Journal of the American Water Resources Association 8(1): 150-160.
3. Custodio E, Bruggeman GA (1987) Groundwater problems in coastal areas. Studies and Reports in Hydrology (UNESCO) 45, France, pp. 1-610.
4. Gambolati G, Putti M, Paniconi C (1999) Three-Dimensional Model of Coupled Density-Dependent Flow and Miscible Salt Transport. In: Bear J, Cheng AD, Sorek S, Ouazar D, Herrera I (Eds.), Seawater Intrusion in Coastal Aquifers-Concepts, Springer, Netherlands, pp. 315-362.
5. Mahesha A, Nagaraja SH (1996) Effect of natural recharge on sea water intrusion in coastal aquifers. Journal of Hydrology 174 (3-4): 211-220.
6. Papadopoulou M, Karatzas G, Koukadaki M, Trichakis Y (2005) Modeling the saltwater intrusion phenomenon in coastal aquifers-A case study in the industrial zone of Herakleio in Crete. Global NEST J 7(2): 197-203.
7. Narayan KA, Schleeberger C, Bristow KL (2007) Modelling seawater intrusion in the Burdekin Delta Irrigation Area, North Queensland, Australia. Agricultural Water Management 89(3): 217-228.
8. Yuansheng P, Zhaohui T (2009) Integrated project management of sustainable water storage and seawater intrusion prevention in a costal city. IEEE: 263-267.
9. Luyun R, Momii K, Nakagawa K (2011) Effects of Recharge Wells and Flow Barriers on Seawater Intrusion. Ground Water 49(2): 239-249.
10. Allow K (2012) The use of injection wells and a subsurface barrier in the prevention of seawater intrusion: a modelling approach. Arabian Journal of Geosciences 5(5): 1151-1161.
11. Abdalla OE, Al Rawahi A (2013) Groundwater recharge dams in arid areas as tools for aquifer replenishment and mitigating seawater intrusion: example of AlKhod, Oman. Environmental Earth Sciences 69(6): 1951-1962.
12. Lahr JH (1982) Artificial Ground-Water Recharge: A Solution To Many US Water-Supply Problems. Ground Water 20(3): 262-266.
13. Todd DK (1974) Salt-water intrusion and its control. Journal (American Water Works Association) 66(3): 180-187.
14. Abd Elhamid H, Javadi A (2011) A cost-effective method to control seawater intrusion in coastal aquifers. Water Resources Management 25(11): 2755-2780.
15. Hussain MS, Javadi AA, Ahangar AA, Farmani R (2015) A surrogate model for simulation-optimization of aquifer systems subjected to seawater intrusion. Journal of Hydrology 523: 542-554.
16. Unep (1998) Source Book of Alternative Technologies for Freshwater Augmentation in Some Countries in Asia. United Nations Environment Programme, Kenya.
17. Sakthivadivel R (2007) The groundwater recharge movement in India. The agricultural groundwater revolution: Opportunities and threats to development 3: 1-16.
18. Misra AK (2014) Climate change and challenges of water and food security. International Journal of Sustainable Built Environment 3(1): 153-165.
19. Spellman FR (2004) Wastewater Treatment and Current Trends. In: Dorf RC (Ed.), The Engineering Handbook. (2nd edn), CRC Press. USA, pp. 1-3080.

20. Spellman FR (2013) Wastewater Treatment Operations. Handbook of Water and Wastewater Treatment Plant Operations, (3rd edn), CRC Press, USA.

21. OECD (2013) Environment at a Glance 2013: OECD Indicators. OECD Publishing, France.

22. Kauffmann C (2011) Financing Water Quality Management. International Journal of Water Resources Development 27(1): 83-99.

23. Bekele E, Toze S, Patterson B, Higginson S (2011) Managed aquifer recharge of treated wastewater: Water quality changes resulting from infiltration through the vadose zone. Water Res 45(17): 5764-5772.

24. Shammas M (2008) The effectiveness of artificial recharge in combating seawater intrusion in Salalah coastal aquifer, Oman. Environmental Geology 55(1): 191-204.

25. Vandenbohede A, Van HE, Lebbe L (2009) Sustainable groundwater extraction in coastal areas: a Belgian example. Environmental Geology 57(4): 735-747.

26. Hussain MS, Javadi AA, Sherif MM (2016) Artificial recharge of coastal aquifers using treated wastewater to control saltwater intrusion. Cardiff University. UK, p. 1-4.

27. Koussis AD, Georgopoulou E, Kotronarou A, Mazi K, Restrepo P, et al. (2010) Cost-efficient management of coastal aquifers via recharge with treated wastewater and desalination of brackish groundwater: application to the Akrotiri basin and aquifer, Cyprus. Hydrological Sciences Journal 55(7): 1234-1245.

28. Kourakos G, Mantoglou A (2011) Simulation and Multi-Objective Management of Coastal Aquifers in Semi-Arid Regions. Water Resources Management 25(4): 1063-1074.

29. Kourakos G, Mantoglou A (2013) Development of a multi-objective optimization algorithm using surrogate models for coastal aquifer management. Journal of Hydrology 479: 13-23.

30. Hussain MS, Javadi AA, Sherif MM (2017) Assessment of different management scenarios to control seawater intrusion in unconfined coastal aquifers. Journal of Duhok University 20(1): 259-275.

31. Javadi A, Hussain M, Sherif M, Farmani R (2015) Multi-objective optimization of different management scenarios to control seawater intrusion in coastal aquifers. Water Resources Management 29(6): 1843-1857.

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