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Artificial recharge of groundwater in semi-arid and humid areas – experiences and new developments

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Abstract

Artificial recharge has a long tradition in semi-arid climates in the form of water harvesting. Large scale water supplies in the humid zone utilise pond recharge, a practice which has been in use for more than hundred years and thus appears sustainable. Well recharge requires usually a very good quality of the recharge water, but a new type of well recharge seems to accept even muddy surface water. Treatment of water for removal of organic matter, iron and nitrate requires carefully designed conditions. Artificial recharge in coastal areas is being commonly used to prevent salt water intrusion.

INTRODUCTION

Artificial recharge of groundwater is not a new approach to sustain groundwater supply. In Central Europe it dates back to the 19th century. It is practised in three forms, pond recharge, well recharge and induced recharge. Pond recharge can be applied in the case of open aquifers while well recharge is required for confined aquifers. Induced recharge is practised since long back along river shores in Europe , e.g. along the river Rhine. However, in arid and semi-arid areas artificial recharge has a far longer tradition in the form of water harvesting. Traditional water harvesting is described in the Indian publication "Dying wisdom" with the function of increasing groundwater recharge (Agarwal and Narain, 1997). Similar practices have been in use for hundreds of years in the Middle East and in Africa (Reij et al., 1996). A water harvesting system, about 2500 years old, has been re-established in Israel at Avdat in the Negev desert (Yair, 1983).

ARTIFICIAL RECHARGE IN EUROPE

Artificial groundwater recharge may have mainly two purposes, to increase the groundwater availability and as a water treatment. In humid areas like in northern Europe both aspects are important. The types of artificial recharge practised are:

Pond recharge

Well recharge
Induced recharge

The use of ponds in glacifluvial deposits for groundwater recharge has been practised for 100 years in Sweden, both to remove organic matter and to increase groundwater resources. The glacifluvial deposits are commonly so called eskers, elongated structures form by glacial rivers. About 25 % of the water supply in Sweden is through artificial groundwater recharge through pond infiltration. A daily recharge rate of 1-2 m is a common figure (Hanson, 2000). A recent evaluation of a 50 year old plant indicate that the practice is sustainable, no accumulation in the aquifer seems to occur neither with organic matter nor with suspended mineral matter from the infiltrated surface water (Jacks, 1999). The large portion of organic matter as well as minerogenic matter is retained in the upper 10 cm of the filter sand and is removed during yearly washing of the top section of the filter. In Finland a natural forested soil profile is used for sprinkling recharge with a very good removal of organic matter as a result. The only side effect is a moderate increase of the nitrate content in the groundwater due to nitrification in the forest floor (Lindroos et al, 1998; Paavolainen et al, 2000). A prerequisite for the good function of the practice is the shadow of a rather closed forest stand which prevents clogging by algal growth of the soil surface.

Induced recharge is common along European rivers and may be more or less planned. Norway is a mountainous country with rather small groundwater resources but abundant surface water while induced infiltration is commonly practised. Along the river Rhine "shore filtration" is a common pre-treatment of the river water. A common problem with induced infiltration is elevated contents of manganese and iron due to anoxic conditions in the bottom sediments of the water course or the lake from which water is drawn (Hanson, 2000).

Artificial recharge smoothes out the temperature variations in a surface water over the year which diminishes problems with seasonal bacterial growth in the distribution system (Peters, 1996). In aquifers with a more complicated geometry it may be difficult to recover the infiltrated water and this may often be manifested as a poor quality of the water. Tracer tests may be needed to assess the rate of recovery and the residence time in the aquifer (Maxe et al., 1998). In general, such tests performed in glacifluvial deposits in Sweden indicate an irregular flow pattern mirroring the inhomogeneous character of such deposits.

A common problem in humid climates is elevated iron content of the groundwater. This is often treated by aeration and re-infiltration of the groundwater. The ferric precipitates are normally retained in the upper 5 cm of the filter sand (Frycklund and Jacks, 1997). Manganese precipitates may sometimes occur where the filter sand rests on the original aquifer material which is often coarser thus creating a capillary breaking layer (Frycklund, 1998). A more advanced treatment is offered by the VYREDOX arrangement in which recharge wells are placed in a circle around the extraction well (Seppanen, 1992). This arrangement provides in situ precipitation of the iron. Clogging of the aquifer seems to occur only on a perspective of many decades.

ARTIFICIAL RECHARGE IN ASIA AND AFRICA

Some types of artificial recharge used in Africa and Asia are:

Water harvesting in general
Tanks
Subsurface dams
Well recharge

Artificial recharge offers a good possibility of storing the water from the wet season to the dry. This is utilised in semi-arid areas in India by the tank system. Most of the tenths of thousands of tanks in Tamil Nadu in India have a downstream well which is recharged from the tank (Palanisami and Balasubramanian, 1998). Drilling of deep bore-wells has for irrigation has however resulted in neglected maintenance of the tanks. The availability of commercial fertilizers has decreased the interest in removing and bringing back the silt from the tanks to the agricultural fields. Pond recharge can easily be practised for unconfined aquifers. For confined aquifers well recharge is an alternative.

In Egypt groundwater recharge is tested to over-bridge year to year variations in irrigation water availability. In the fringe of the Nile delta a recharge rate of 0,13-0,40 m/day can be achieved (Attia et al, 1998).

While much of the water harvesting systems used in the Middle East and Africa are aimed at collecting water for agricultural purposes (Reij et al., 1996) the users are also generally well aware of the benefit for the groundwater availability. Traditional technologies are especially well developed in the mountainous region Pay Dogon in the Republic of Mali in West Africa.

Sub-surface dams, barriers across stream beds with an impermeable material attached to the rock surface, aimed at arresting groundwater runoff has been applied in India and Ethiopia (Hanson and Nilsson, 1986).

Artificial recharge is considered as a water economising measure i Kuwait (Viswanathan and Al Senafy, 1998). Artificial recharge of treated sewage water is one of the counter-measures considered for preventing saline intrusion in the heavily populated Ghaza strip in Palestine (Hamdan, 1999). It is anticipated that also denitrification will be achieved in this case.

Reduction of fluoride content in groundwater has been achieved be artificial recharge (Dr M. Athavale, NGRI, Hyderabad, personal comm.). Combining this with water harvesting in tanks and treatment of the tanks with gypsum should improve the results (Jacks et al., 2000).

WELL RECHARGE

Well recharge requires normally a very good water quality. In Holland well recharge is practised in the sand dune areas with meticulously treated water from the river Rhine. By carefully controlling the flow pattern denitrification can be achieved in the aquifer (Stuyfzand and Kooiman, 1996; Stuyfzand, 1998). A clogging handbook which takes up the physical processes by which clogging can occur and how it can be avoided has been produced within a European project (Pérez-Paricio and Carrera, 1998 and 1999).

A fairly simple indigenous type of recharge well has been developed in the drought prone Kacchh peninsula in Gujrarat for the recharge of a confined aquifer at about 30- 50 m depth (Raju and Ferroukhi, 1996). The recharged water is surface runoff during the monsoon which is collected in tanks. In the tank a large sand filter, 5x5x5 m, dug into the bottom of the tank provides filtration of the water before it enters into the recharge well. The surface sand has to be replaced every year. Such type of recharge has now been in use for nine years without visible signs of clogging. The recharge scheme in Kacchh has also a water quality aspect as the recharge provides a barrier against saltwater intrusion from the coastline.

CONCLUSIONS

Artifical recharge is applied under very various climatic and environmental condition. It has been used since time eternal in Asia and Africa especially for water harvesting purposes. Nowadays artificial recharge is also often used for water treatment like removal of organic matter and iron. Another important application is to prevent seawater intrusion. Several investigations indicate that artificial recharge is a sustainable technology, that clogging of the aquifer does not occur if the maintenance is done in an appropriate way. Traditional designs are to be preferred in developing countries due to the small investments required and the ease of maintenance. New development are found especially in the field of well recharge.

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