التوثيق

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Arab Organization For Agricultural Development

GROUNDWATER MINING IN THE ARAB REGION AND PROSPECTS FOR IMPROVEMENT OF AQUIFERS RECHARGE

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Groundwater mining in the Arab Region
and prospects for the development of artificial recharge

Abstract

During the last decades there has been tremendous growing stress on water resources in the Arab Region in order to meet various human water needs for irrigation , industries and drinking water supply. This situation has resulted in the overexploitation and mining of large number of groundwater aquifers in the Arab Region and deterioration of their quality due to seawater intrusion in coastal aquifers . The depletion of groundwater levels due to overexploitation has also resulted in some cases in disastrous economical consequences due to the cost of pumpages .

As water resources are very limited in this Region which is characterized by severe arid conditions efforts have been concentrated on rational utilization and the development of these resources, through the implementation of appropriate techniques of water mobilization and conservation.

Among these techniques being extensively used since recently in the arid and semi arid regions, the improvement of aquifers recharge .

When the local hydrological and hydrogeological conditions are fairly suitable for the implementation of such techniques, artifical recharge of aquifers may constitute an important tool to alleviate groundwater mining . This is very important for arid and semi arid areas where important quantities of floods and overland flows are frequently lost to the sea and by evaporation.

The present paper will review some cases of groundwater mining in the Arab Region and the prospects for the improvement of groundwater recharge in order to protect these resources against overexploitation .

SCOPE OF GROUNDWATER MINING IN THE ARAB REGION

Groundwater resources in the Arab Region which is characterized by arid and semi arid climate play an important role in the economical and social development in these regions. However these resources have been undergoing a tremendous overexploitation due to increasing water needs in this region.

This situation has often led to groundwater mining in numerous areas, with a disastrous consequences, particularly in the coastal aquifers which are contaminated by seawater intrusion.

The current situation is particularly grave in the coastal aquifers of the North African Countries and the Gulf States where the salinity of groundwater, due to seawater intrusion , may often goes beyond 10 g/l.

This limits of course the utilization of ground water for irrigation and drinking water supply . Also the mobilization of new water resources in this Region is often very costly and technically very difficult . Groundwater mining results very often in a considerable depletion of the water table which implies a substantial increase in the cost of pumpage and might jeopordize numerous agricultrual projects.

In view of this situation , the water authorities in the Arab Region are nowadays pursuing a new water resources management approach based particularly on groundwater protection and conservation.

Within this framework, **ground artificial recharge** is used as an effective technique to replenish the aquifers by surface runoff or other non conventional water resources. This technique , when properly practised , allows in fact the storage of important quantities of streamfloods into groundwater reservoirs, to be exploitated later for various utilizations . But the success of groundwater artificial recharge depends on certain number of hydrological, hydrogeological and environmental factors.

CASES OF GROUNDWATER MINING AND IMPROVEMENT OF AQUIFER RECHARGE IN THE ARAB REGION

1- Groundwater mining and improvement of the souss aquifer recharge in Morocco : Case of the Souss aquifer.

The Souss coastal aquier in Morocco is located on the coast of the Atlantic Ocean with its borders the High Atlas to the North ; the Anti Atlas to the South and the Atlantic Ocean to the West . The area of the aquifer is about 4000 km2 . the annual rainfall in the basin varies between 250 mm in the plain and over 600 mm in the High Atlas . The Souss Watershed is drained by the Souss river which flows into the Atlantic Ocean . This main river is sort of a flood stream and flows a few months per year where much of the floods used to be lost to the sea . Therefore only part of these floods are used to recharge the aquier, particularly in the upstream part of the aquifer . It is estimated that about 80 million cubic / year the total volume of natural recharge in this area . The hydrogeology of the aquifer is mainly characterized by fluvial -lacustre deposits constituting a series of marl-limestone with interclation of coarse alluvial material in between ; the transmissivity of the aquifer varies between 10^{-2} and 10^{-3} m2 /s .

Exploitation of the aquifer

The Souss aquifer undergoes very high rate of pumpage to meet water demand of the irrigated scheme called "Souss Massa" . The overall pumpage from the aquifer has increased from 240 Mm3 to 400 Mm3 per year within a period of 15 years . As a result of this overexploitation of the aquifer groundwater has been depleted at a rapid rate during the last two decades - this situation has been aggravated by the occurence of very severe draught which hit the region since 1972. As a matter of fact the depletion of groundwater table has been increased at a rate of 10 to 20 meters during the period 1968 - 1986 as follows :

- 10 m in the coast border
- 10 - 20 m along the main river
- 30 - 40 m in the area of Geurdane where high pumpage for irrigation is concentrated .

The water balance of the aquifer shows that the actual groundwater deficit is about 260 Mm3/ year on the average and varies between 150 Mm3 and 310/Mm3 per year . The losses by drainage to the sea are estimated of about 135 Mm 3/ year on the average and vary between 250 Mm3 during the humid seasons and 55 Mm3 during the period of drought. These figures show therefore that the actual flood losses to the sea do cover only about half of the deficit of the aquifer .

Therefore it appears very clear that the protection of the aquier against further depletion and deterioration of its quality needs to enhance the natural recharge through storage of the maximum of the floods generated at the upstream part of the river basin - these measures must be necessarly accompanied by efficient integrated surface water - groundwater management approaches to ensure a sustainable development of the irrigated scheme in the Souss Area without jeoperdizing the storage of groundwater resources. For this purpose the Water Authorities have proceeded with the construction of the Aoulouz dam reservoir on the Souss main river. The main goal of this dam is to store much of the floods during the rainy season to be released gradually in order to enhance the natural recharge of groundwater and reduce surface flow losses to the sea. The project includes also a management of the bed and banks of the river and its tributaries in order to enhance infiltration during the period of overflow and during the releases of flows from the dam reservoir .

The dam has been commissioned since recently and now the Water Authorities are proceeding with the assessment of the performance of the project - But so far the preliminary obtained results are very encouraging since very significant replenishment of the aquifer is being observed .

2- GROUNDWATER MINING AND IMPROVEMENT OF AQUIFER RECHARGE IN CHARF AKAB IN MOROCCO.

This aquifer has been used to provide drinking water supply to the city of Tangiers on the Mediterranean coast. The area of the aquifer is about 20 km2 and located at 20 km at the South East of the City of Tangiers - its total volume is about 2.5 billion m3 - the natural recharge is very low , only about 2 Mm3/year from the rainfall. Goundwater is stored within a confined aquifer which is contained within the following geological layers :

- Sandstone layers on the top.
- Marls in the Middle (impervious layer)
- Coarse limestone
- Impervious bed rock at the bottom.

In the late fifties the storage of the aquifer has been almost exhausted and could not secure any more the total needs of drinking water supply.

Therefore the Water Authorities have proceeded with the replenishment of the aquifer by injection into the aquifer about 20.000 m3/day , through the Karsts, the floods generated in the stream of Oued M ' HARHAR . This has resulted indeed in very significant replenishment of the aquifer , but this improvement could not be maintained further because of the growing pumpage; and during the period 1964 - 1978 we noticed again a gradual depletion of groundwater .

Therefore the Authorities were obliged to construct a dam - reservoir "Ibn - Battouta" of a storage capacity of 26 Mm3 to help cope with the growing urban water demand . So the system of water provision to the city is being actually made by using joint surface water and groundwater as follows :

- During the rainy season (November - May) , the urban supply is entirely provided by the dam-reservoir ; about 82500 m3/ day are released to the treatment station ; also part of the treated surface water from the reservoir is used for injection into the aquifer.

- During the dry season (May - October) abstraction from the aquifer could be used to supplement , if needed , the provisions from the dam reservoir .

At the begining of the nineghties the growing urban water demands have gone beyond of what could provided by the current water supply system and therefore the Authorities have launched the construction of another dam on the stream of Oued Hachef, which is expected to provide up to 120.000 m3/day to supply the cities of Tangiers and Asilah .

COMPATIBILITY OF VARIOUS ARTIFICIAL RECHARGE TECHNIQUES WITH THE CHARACTERISTICS OF THE SITE

Artificial recharge technique	groundwater level	type of the stream flow	Topographic conditions of the site
Artificial recharge by infiltration basins in parallel	Deep groundwater level (> 30 - 40 m)	Adapted for stream flow duration of at least 3 months	Adapted to irrigular topogaphy
Artificial recharge by infiltration basins in series	groundwater level (> 20 m)	duration of stream flow 1 month at least	could be adp-ted to hilly topographic conditions
Artificial recharge by management of the stream bed	shallow groundwater level	un controled floods of long duration	No high slop of the stream bed
Artificial recharge by flooding	no constraints	adapted for short time floods	No constraints

NEED FOR SMALL SCALE PILOT PROJECTS PRIOR TO THE IMPLEMENTATION OF LARGE SCALE ARTIFICIAL RECHARGE PROJECTS

Prior to the implementation of large scale groundwater artificial recharge either by streamfloods or waste water, it is necessary to conduct some preliminary site experiments in order to investigate :
- the hydraulic and environmental impact on groundwater ,
- the performance of the artificial recharge system and its viability .
This latest point is of particular concern because it seams that, in many operational projects worldwide, the recharge kinetics decreases significantly with time due to various reasons related to clogging of the porous medium, rise in groundwater table, etc.

Nowadays with the advancements of the computer techniques, modelling of the overall artificial recharge system is very often used to investigate its performance and viability .
Numerical model may allow the simulation of various pattern of artificial groundwater artificial recharge, and the computation of the overall design parameters .

ADVANTAGES AND CONSTRAINTS ASSOCIATED WITH GROUNDWATER ARTIFICIAL RECHARGE

Groundwater artificial recharge consists of providing water supply to groundwater reservoirs by percolation or injection of surface water . Under natural conditions only small fractions of rainfall and streamflow reach groundwater, and considerable quantities of the rest of these resources are lost to the sea and by evaporation . Therefore the artificial recharge has been developed in order to enhance the natural recharge through the implementation of various techniques .

a. Advantages :

When appropriate hydrological, hydrogeological and environmental conditions exist, groundwater artificial recharge could present the following advantages :

- storage of important quantities of streamfloods into groundwater resources .
- reduction of the incidences of groundwater mining .
- reduction of the risks of seawater instrusion into coastal aquifers .
- reasonable coast of investment and operation .

b. Constraints :

The major constraints which have been noticed in a number of groundwater artificial recharge projects are mainly associated with :

- the complexity of the managment of the system, particularly maintenance and monitoring .
- the long term viability of the system which results in some incertainties of the economical feasibility of the artificial recharge projects .
- the risks related to groundwater contamination .

APPROPRIATE CONDITIONS FOR GROUNDWATER ARTIFICIAL RECHARGE

1. Hydrological :

The implementation of artificial recharge requires the availability of sufficient quantities of surface waters in order to secure a significant replenishment of groundwater at a reasonable economical cost . Also the surface waters used in artificial recharge should contain very low concentration of sediments to avoid serious clogging of the subsoil .

This latest issue is in general the major constraint to groundwater artificial recharge, particularly in the arid and semi arid regions where streamflows are very loaded with suspended solids, exceeding very often 50 g\l during the flood periods. .

In these conditions the artificial recharge facilities must necessary integrate into the system a sediment trap devices . While this would increase the cost of investment and operation, it would secure the viability of the recharge facilities .

It is therefore necessary to conduct a preliminary field survey about the time variation of the streamflow as well as the seasonal variation of the concentrations of the suspended solids in order to secure properly the design of the artificial recharge facilities .

2. Hydrogeological :

The most appropriate geological formations suitable for groundwater artificial recharge are those predominantly granular, fissered or karstic, because of their high permeabiltities. while the granular formations usually allow the recharge and storage of large quantities of surface waters, the karstic aquifers can not provide much of the storage because of groundwater high velocities within the karstic rocks .

The suitability of aquifers for artificial recharge depends also on several other factors such as :

a. the depth of the water table : in shallow aquifers, artificial recharge may be difficult due to insufficient percolation .

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a. the depth of the water table : in shallow aquifers, artificial recharge may be difficult due to insufficient percolation .

b. the tickness of the non saturated zone .

c. the structure and tickness of the saturated zone with regard to the positions of the existing local springs and streams .

d. Transmissivities :

This is very important factor in groundwater artificial recharge : need for sufficient tickness of the aquifer and sufficient permeability . It should be noted that if the tickness of the aquifer is not sufficient enough, the groundwater reservoir may have only small storage capacity; likewise if the permeability is low, the artificial recharge may require large areas for infiltration which is technically and economically not suitable .

e. Storage capacity of the aquifer :

In most of groundwater artificial recharge projects, the stored surface waters should be conserved underground for a certain period of time before it could be used later during the drought . For this reason the recharged aquifers should have enough storage capacity in order to secure adequate regularization of groundwater .

f. Environmental :

The quality of surfacewater to be used in groundwater artificial recharge is an important factor which might have a detrimental environmental effect on groundwater if it is not properly handeled . This issue is of particular concern especially when it comes to use water mixed with municipal and industrial sewage and with agricultural drainage .