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Pumping and injection of surplus desalinated seawater as part of the new management of the groundwater resources in Israel

Pompaggio e iniezione di acqua di mare dissalata in eccesso nell'ambito della nuova gestione delle risorse idriche sotterranee in Israele

Joseph Guttman

Riassunto: Per molti anni le acque sotterranee sono state la principale risorsa idrica in Israele. Affidarsi per anni alla risorsa immagazzinata nelle falde acquifere ha abbassato il livello dell'acqua vicino alle linee rosse ed ha esposto le falde acquifere a rischi di salinizzazione. Si prevede che l'effetto del cambiamento climatico porterà a un'ulteriore riduzione di circa il 2% all'anno delle precipitazioni e a una riduzione a lungo termine della ricarica degli acquiferi. Tali condizioni hanno indotto il governo di Israele a produrre acqua desalinizzata dal mare come nuova risorsa idrica artificiale, riducendo parallelamente il pompaggio delle acque sotterranee e ristabilendo lo stoccaggio delle falde acquifere.

Durante i periodi di bassa domanda c'è un'eccedenza di acqua di mare desalinizzata di alta qualità per ore o giorni che può essere temporaneamente iniettata e immagazzinata nelle falde acquifere e successivamente pompata durante il periodo di alta domanda.

Fondamentalmente, la ricarica artificiale viene eseguita in molti modi e tecniche. I modi più comuni sono l'infiltrazione in bacini o attraverso pozzi di iniezione. Questo lavoro si concentra sulle attività svolte nei pozzi di iniezione.

Il risultato principale ottenuto nelle zone pilota è stato che il nuovo design e la tecnica di costruzione dei pozzi di iniezione hanno ridotto drasticamente le perdite di pozzo e migliorato la capacità specifica (portata oraria rispetto al prelievo dinamico) durante l'iniezione.

Una corretta strategia per la ricarica in condizioni controllate degli acquiferi (in inglese Managed Aquifer Recharge - MAR) dovrebbe combinare bacini di infiltrazione con pozzi di iniezione per iniettare l'acqua in eccesso insieme a batterie di pozzi di pompaggio per pompare l'acqua iniettata in breve tempo durante i periodi di forte domanda.

Keywords: *desalinated seawater, Managed Aquifer Recharge, artificial recharge, injection wells. .*

Parole chiave: acqua desalinizzata dal mare, ricarica delle falde in condizioni controllate, ricarica artificiale, pozzi di iniezione.

Abstract: *: For many years, groundwater was the main water resource in Israel. Relying for years on the storage of the aquifers dropped their water level close to their red lines and exposed the aquifers to salinization hazards. Climate change effect is expected to lead to additional reduction of about 2% per year in the rainfall leading to long term reduction in the aquifers recharge. Those conditions brought the Government of Israel to produce desalinated seawater as a new artificially water resources reducing the groundwater pumping and rehabilitating the aquifers storage.*

During low demand periods there is a surplus of high-quality desalinated seawater for hours or days that can be temporary injected and stored in the aquifers and later pumped during high demand period.

Basically, artificial recharge is done in many ways and techniques. The most common ways are injection in infiltration ponds or through injection wells. This paper is focused on activities that were done in injection wells.

The main outcome from the pilots was that the new design and construction of the injection wells reduced dramatically the well loss and improved the specific capacity (hourly discharge versus the dynamic drawdown) during the injection.

Proper Managed Aquifer Recharge (MAR) should combine infiltration ponds with injection wells for injecting the surplus water together with batteries of pumping wells for pumping the injected water in short time during high demand periods.

Joseph GUTTMAN
J.G.H. Consulting, Mekorot, Israel National Water Co.
email: yosgut@gmail.com

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Introduction

Israel is located in a semi-arid zone, characterized by large changes in monthly and yearly rainfall between years. These effects cause series of rainy years along with series of drought years.

For many years, groundwater was the main water supply resource. The average yearly natural recharge into the groundwater basins is around 1,600 Mm^3/ year. Of these, about 1,000 Mm^3/year in an average year can be used as freshwater resource, when the annual freshwater consumption is about 1,400 Mm^3/year.

Many actions were done to overcome between the natural water resources (surface water and groundwater) and the water consumptions, like: temporary overexploitation from the aquifer storage, development of deep groundwater sources that have larger and deeper storage and are less effected by yearly changes in the rainfall, reuse of treated domestic effluent in agriculture and shifting the fresh water that was used in agriculture for domestic purposes. Today, almost 90% of domestic wastewater is treated for reuse in agriculture (about 350 Mm^3/year).

Relying for years only on the storage of the aquifers drastically dropped their water level and exposed them to salinization hazards. In drought years, reducing temporarily the freshwater quotas for the agricultural sector was the main tool to diminish the gap between the natural recharge and the demand. Therefore, the agricultural sector was used as a "water deficit buffer". Climate change effect is expected to lead to a reduction of about 2% per year in the rainfall leading to long term reduction of the aquifers recharge. All of this leads to the situation that in the coming future, the percentage of groundwater in the total consumption will decrease.

After the extreme drought period occurred in Israel at the beginning of the Millennium, which created a severe hydrological deficit in the aquifers, the Government of Israel decided to build several desalination plants along the Mediterranean Sea shore to produce new artificially water resources. Adding desalinated seawater into the water supply network made it possible to reduce the pumping from the aquifers rehabilitating their storage.

The article focuses on the activities for renewing the injection capability through wells in the coastal aquifer of Israel to recharge surplus desalinated seawater for seasonal storage.

The sea shore desalination era

Since 2005, the water sector in Israel is changing dramatically due to the construction of the sea desalination plants. Between 2005 and 2015, five large seawater desalination plants along the Mediterranean coast were established. According to the Israel Water Authority data (www.water.gov.il), the total desalinated seawater production reached 600 Mm^3/year in 2019. The desalination plants are connected to the main national carrier pipelines and are integrated in the national water management.

From economic reasons, sea desalination plants are producing water all over the year. In parallel, the pumping from the aquifer reduced to period of 3-4 months per year, during the summertime and high demand peaks.

During low demand periods (mainly in the winter and weekend), there is a surplus of high-quality desalinated seawater for short time as shown in Figure 1. The results in Figure 1 present the surplus water in an average demand and consumption year.

Using the aquifer as a temporary storage for the surplus water, injecting it through injection wells or in infiltration basins and afterward pumping it during high demand period, is part of the Managed Aquifer Recharge (MAR) method which is included in the Integrated Water Resources Management philosophy (IWRM); (Dillon et al. 2019; Schüth et al. 2019; Escalante et al. 2020).

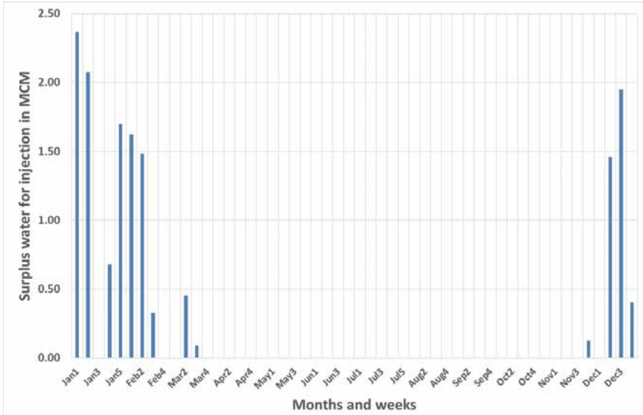

Fig. 1 - Typical weekly surplus of desalinated seawater that is available for injection in the Israel National Water System (Guttman et al 2017).

Fig. 1 - Eccedenza settimanale di acqua desalinizzata disponibile per la ricarica nel sistema idrico nazionale in Israele (Guttman et al. 2017).

Injection well pilots for aquifer recharge in Israel

Artificial recharge via injection wells had started in Israel in the 1950's with injection of water from the Sea of Galilee into the calcareous sandstone of the coastal aquifer and into the limestone-dolomite layers of the Western Mountain aquifer (Guttman 1994; Schwartz and Bear 2016). Beside the injection wells, several infiltration ponds and abandoned quarries were established in the coastal aquifer for injecting surface runoff and excess water during rainy years.

At those time, two kinds of injection wells were constructed: wells only for injection purpose, and dual-purposed wells enabling both the injection of surplus water during the winter and the pumping during high demand seasons. There were many obstacles in the recharging process. The main problem was the high organic content and high turbidity in the Sea of Galilee water that caused rapid clogging processes in the injection wells. Before supplying the water to the customers (in the dual-purposed wells), re-pumping for certain time was necessary to recover the injection capacity and to bring the water to a quality required for drinking purposes. The injection via wells ceased in Israel during the 1990's because of the lack of available water from the Sea of Galilee, and the clogging and technical problems in the old injection wells (Guttman et al 2017) and in the transmission lines. Most of the old injection wells were declared as abandoned wells.

The establishment of the seawater desalinated plants creates surplus water during low demand periods (Figure 1) leading to the decision of renewing the capability of water injection through new injection wells in the coastal aquifer. The advantages in using injection wells in comparison to infiltration ponds is the ability to locate the injection wells in places where the subsurface geology is not suitable for infiltration ponds, in confined aquifer, small and densely populated area, and close to the water supply network.

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"Mekorot"-Israel national Water Company started a program to re-evaluate the feasibility and profitability of injection wells as part of a new MAR policy to handle surplus desalinated seawater. The first site involved drilling of separated production and infiltration wells. The results were summarized by Guttman et al (2017). The lithologies of the aquifer are fine sand and calcareous sandstone with some clay layers in between (Fig. 2). The injection well was equipped with 14" stainless steel 304L casing and screen and well sorted quartz as gravel pack (Fig. 2). In order to obtain high injection rate, the length of the screen section was increased as much as possible beginning the screen section from about 20 meters below the static water level. Guttman et al (2017) showed the differences in the hydraulic parameters between the pumping test and the injection test in the injection well despite both tests being conducted in the same injection well (Fig. 3). They also showed that the rise of the water level during the injection test was greater than the drawdown during the pumping test and that the specific capacity (hourly discharge versus the dynamic drawdown) during the injection test was only 1/3 of the specific capacity in the pumping test (66% reduction).

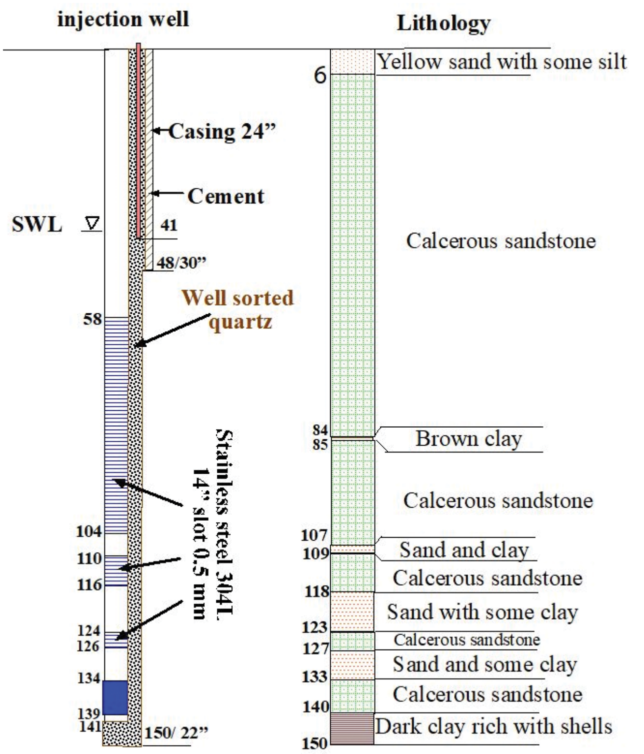

Fig. 2 - Lithology and the construction of the injection well. The static water level (SWL) is shown.

Fig. 2 - Stratigrafia e schema costruttivo di un pozzo di iniezione. Lo schema riporta il livello statico dell'acquifero (SWL) misurato nel pozzo.

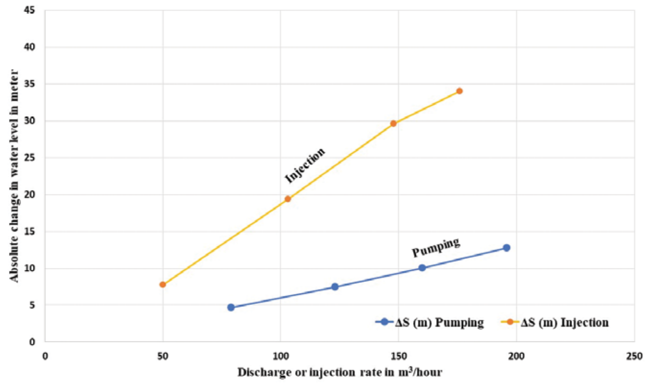

Fig. 3 - The dynamic drawdown against the hourly discharge from the drawdown and the injection tests (Guttman et al. 2017).

Fig. 3 - Abbassamento del livello dell'acquifero e portata oraria durante le prove di pompaggio ed iniezione (Guttman et al. 2017).

The lithologies of the aquifer are fine sand and calcareous sandstone with some clay layers in between (Fig. 4). The dual-purposed well was equipped with 16"x20" 316L Muni-Pak stainless steel casing and screen with glass bead in the space against the screen section and well sorted quartz above it (Fig. 4). The top of the screen started 33 meters below the static water level. The length of the screen section in the dual-purposed well (Fig. 4) is shorter than in the previous injection well (Fig. 2) because the dual-purpose well is also a pumping well and we should leave enough space for the dynamic draw-down without exposing the screen during the pumping stage.

The second site is located about 15 km south of the first site. In the second site a new dual-purposed well was drilled. Dual-purpose well means a pumping well equipped with a pump that is used also for injection.

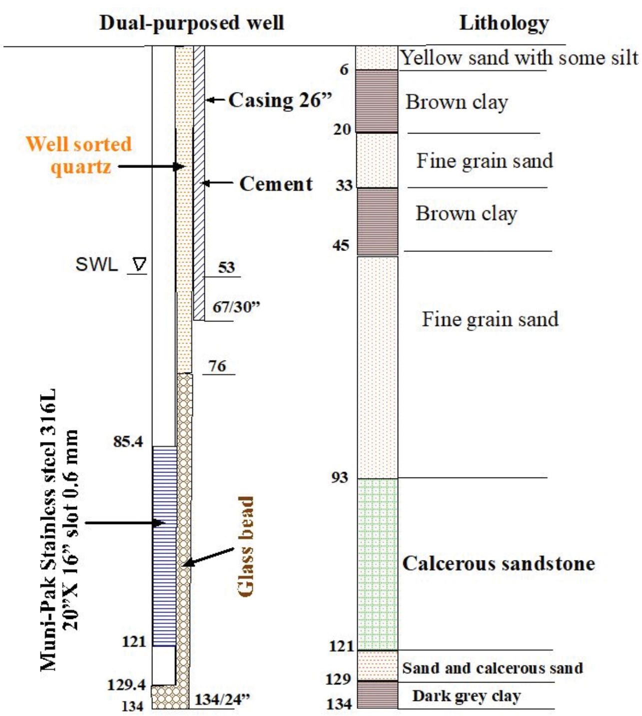

Fig. 4 - Lithology and construction of the dual-purposed well. The static water level (SWL) is shown.

Fig. 4 - Stratigrafia e schema costruttivo di un pozzo di estrazione/iniezione. Lo schema riporta il livello statico dell'acquifero (SWL) misurato nel pozzo.

Pumping and injection tests carried out in the dual-purposed well (Fig. 5) showed that the differences in the drawdown and the rising of the water level were quite small. The comparison of the specific capacity between the pumping and injection tests showed a reduction of only 19% in the injection test compared to the pumping test.

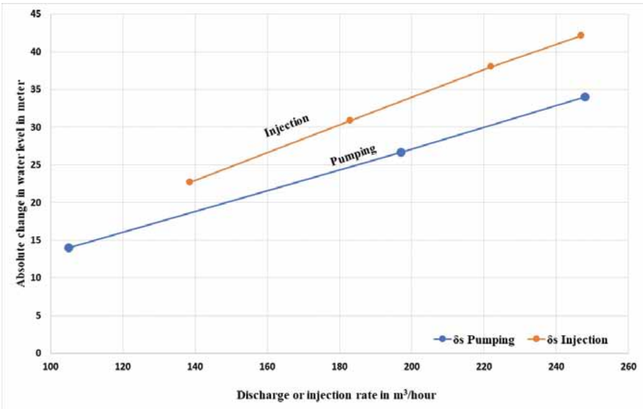

Fig. 5 - The dynamic drawdown or rising against the hourly discharge from the drawdown and the injection tests in the dual-purposed well.

Fig. 5 - Abbassamento o risalita del livello dell'acquifero e portata oraria durante le prove di pompaggio ed iniezione effettuate nel pozzo di estrazione/iniezione.

Discussion and conclusion

Israel locates in a semi-arid zone characterized by large changes in monthly and yearly rainfall between years, resulting in series of rainy years along with series of drought years.

For many years, groundwater was the main water resource and the supply was relying on the storage of the aquifers. During drought years, over-pumping from the aquifers drop their water level and exposed the aquifers to salinization hazards. The agricultural sector was generally used as a "water deficit buffer" by reducing temporarily its freshwater quotas and shifting this amount to the domestic sector.

In addition, climate change is expected to cause an additional reduction of about 2% per year in the natural recharge of the aquifers, leading to long term reduction in the aquifer's storage.

Those conditions brought the Government of Israel to establish several desalination plants along the Mediterranean Sea shore for producing new artificially water resources.

Since 2005, the water sector in Israel has dramatically changed due to the entering of the sea desalination plants. In 2019, the total desalinated seawater production reached 600 Mm^3/year. From economic reasons, the sea desalination plants are producing water all over the year and, in parallel, the pumping from the aquifers is reduced to 3-4 months per year (i.e., mainly during the summer and in high demand peaks).

During the low demand periods in wintertime, there is a surplus of high-quality desalinated seawater that can be temporary stored in the aquifers and later pumped during high demand period. Today, because of the lack in injection wells, only part of the surplus water is injected in some infiltration ponds.

A program for re-evaluating the feasibility and profitability of injection wells was started few years ago. It included drilling of new injection and pumping wells with a new and modern well design. In one site, the injection well was contain long stainless steel screen section and well sorted quartz gravel in the space and in the second site, the injection well was a dual-purposed well using Muni-Pak stainless steel screen with glass bead in the space.

The results from pumping and injection tests conducted in the injection well, show that the specific capacity in the injection test was only 1/3 of the specific capacity in the pumping test (66% reduction). While, in the new dual-purposed well, the specific capacity during the injection test was reduced by only 19% compared to the specific capacity of the pumping test. If we ignore any possible differences in aquifer properties and lithologies between the pilot sites, the pumping test results demonstrate how proper design and proper structure of the injection well can reduce the well loss and can improve the injection capacity and properties.

Proper Managed Aquifer Recharge (MAR) must use the aquifer as a seasonal storage by combining several injection and pumping methods. In Israel, the best combination should result from infiltration ponds and injection wells for recharging the excess water together with batteries of pumping wells located close to the injection sources for pumping the injected water in short time during high demand periods.

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