



Tel Aviv, Israel

Treating wastewater for reuse using natural systems

Tel Aviv has been treating its wastewater for reuse with Soil Aquifer Treatment for several decades; the clean recovered water is then conveyed to the south of the country where it is used to irrigate agricultural crops. However, in response to the aging system's drawbacks, a rising population as well as the increasing need for land for urban settlement around Tel Aviv's periphery, the city has had to find a more appropriate and compact solution for its wastewater treatment needs. Tel Aviv has piloted a modified version of the technology which is not only more effective but also uses less land.



Population: 390,100 (2007)

Land area: 51.4 km²

Soil Aquifer Treatment is one of several natural methods for wastewater treatment. With this method, effluent that has been subjected to pre-treatment is allowed to filter through soil to an underlying aquifer, a process during which natural processes remove most contaminants and organic matter. Tel Aviv has piloted a modified version of this method with reduced infiltration time and added use of nanofiltration. This process has been found to remove pollutants and organic matter to a degree where the reclaimed water is still suitable for irrigation, to be easier to maintain, but also to reduce the land area required for wastewater treatment.

Using this method, Tel Aviv will be able to meet the wastewater treatment needs of its growing population while at the same time preserving land for urban development. Moreover, the city will continue to supply treated wastewater to the south of Israel, whose agricultural areas are dependent upon this relatively economical and clean source of irrigation water.

Effluent treatment and reuse

The provision of clean water is one of the main functions of local governments, nowhere more than in arid and semi-arid countries, where the lack of availability of freshwater can place a constraint on development. An associated task for cities is the proper treatment and reuse or disposal of effluent, which has important consequences in terms of water availability as well as human and ecosystem health.

Technologies allowing for the treatment of wastewater for reuse provide a valuable additional source of freshwater, but also minimize problems linked to wastewater disposal. However, wastewater reclamation systems located near urban areas must meet several criteria, namely low surface area and, depending on the end use of the water, high quality. It is also often desirable for these systems to have low setup and operation costs.

This case study was produced for the SWITCH project (2006-2011), which aimed to achieve more sustainable urban water management in the "City of the Future". A consortium of 33 partner organisations from 15 countries worked on innovative scientific, technological and socio-economic solutions with the aim of encouraging widespread uptake around the world.

www.switchurbanwater.eu

The case study is part of the SWITCH Training Kit, which can be found at www.switchtraining.eu

Tel Aviv in context

Tel Aviv is the second largest city in Israel and is densely populated, with almost 7600 inhabitants per square kilometre. Situated on the Mediterranean coast, the city suffers from the salinisation of local wells and aquifers. This is a problem common along the Israeli coast, where over-abstraction of coastal groundwater leads to saltwater intrusion inland. This reduces the amount of freshwater that can be extracted for municipal, industrial or agricultural use. Industrial and agricultural pollution and population growth are other factors which have led to the depletion of water resources.



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In Tel Aviv and throughout the whole of Israel, the semi-arid climate characterised by seasonal rainfall, increasing water needs and a political desire for water self-sufficiency have led to innovations in water use reduction and water reuse. Tel Aviv is concentrating on the control of pipe leakage as well as the reuse of water, for example through dual systems allowing for the separation and reuse of greywater. The city is also exploring ways to increase water supply, for instance through desalination, yet the seasonal rainfall also compels the city to implement effective stormwater management practices.

Population growth and rapid urbanisation have been major factors driving the city to revise its wastewater treatment practices. Tel Aviv has started to prioritise decentralised and compact wastewater treatment systems, which offer greater flexibility in dealing with load increases compared to centralised treatment facilities at a lower cost and using a smaller land area. As Tel Aviv expands, the land surrounding it has become more valuable for urban development, and therefore too expensive for agricultural use. This increasing need for land at the periphery of cities in Israel has been one of the driving forces for the expansion of irrigated agriculture in the country's arid south, which has been facilitated by the availability of treated wastewater, such as that produced by Tel Aviv's Soil Aquifer Treatment method.

Tel Aviv's main priorities in relation to water are to ensure a safe and uninterrupted water supply, to improve the safe reuse of reclaimed effluents and to implement effective flood control. The natural treatment method described here can also help manage winter stormwater flows more effectively by providing large storage areas for excess runoff.

Wastewater reclamation in Israel

Reclamation of wastewater remains a priority in Israel as a whole; indeed, Mekorot envisages that its share in the national sources of freshwater will increase from 15% in 2005 to 20% in 2020. Given projected water use increases, this will mean an important increase in reclaimed wastewater quantities. Israel as a whole reuses over 75% of its effluent, which is a high percentage in comparison with other countries; it aims to increase the reuse percentage to 90% by 2020.

Soil Aquifer Treatment of wastewater

Tel Aviv has been running a system of treatment and reuse of wastewater since the 1970s. Soil Aquifer Treatment (SAT) has enabled the safe and effective reclamation of much of the city's wastewater, for use in agricultural irrigation. Limitations of the existing SAT technology have however led the city to explore modifications to the system, changes which have been successfully piloted through the SWITCH project.

Conventional Soil Aquifer Treatment

Soil Aquifer Treatment (SAT) involves the infiltration of effluent which has been subjected to secondary treatment into a groundwater aquifer through a soil percolation zone. The natural physical, chemical and biological processes that take place in the soil and aquifer remove chemical and microbiological contaminants present in the effluent. It is then possible to extract and reuse the water which has percolated beyond the treatment zone. Soil Aquifer Treatment increases the sustainability of wastewater treatment. It avoids the disposal to the sea of a potentially valuable resource, making it an economically viable solution, as well as the use of potable water for non-potable purposes such as irrigation.

Conventional wastewater management is a linear process, consisting of inputs, in the form of mixed wastewater flows, and outputs, namely treated effluent and sewage sludge. Conversely, more sustainable wastewater treatment involves a more cyclical process, with the separate collection, treatment and reuse of the different wastewater flows allowing for cost reduction and resource recycling. In the treatment phase, SAT is a more natural approach to wastewater treatment than the typical systems that are in place. These usually consist of three or four treatment phases, which can be of several different types, but are generally energy and chemical intensive.

A typical plant would use pre-treatment, involving the removal of larger particles through screening for instance, followed by primary treatment, where sludge is settled in mechanical sedimentation tanks. Many different secondary treatment options exist; one example is rotating biological contactors, which promote the growth of bacteria and micro-organisms that break down organic matter. The purpose of tertiary treatment is to improve the quality of the effluent discharged into the environment – it typically involves the removal of nutrients through various means.

By collecting greywater separately and implementing SAT, the Tel Aviv approach to wastewater management is considered to be more sustainable than the conventional one. In Tel Aviv, the SAT replaces tertiary treatment, while at the same time producing effluent of a much higher quality standard. Tel Aviv's existing SAT zone has been operational since 1977 and is located at the Shafdan wastewater treatment plant which is operated by the national water utility Mekorot. In order to improve the quality of the wastewater that is conveyed to the Shafdan plant, a collection and treatment system for oil and grease as well as a salt separation system have been established. Subsequently, upon arrival at the plant, Tel Aviv's and its surrounding municipalities' wastewater is subjected to pre-treatment screening and separation as well as primary and secondary treatment using mechanical and biological means.

The wastewater is then spread onto six SAT recharge basins, where it is absorbed by the soil and channelled to the groundwater. The retention time of the liquid effluent prior to reuse is usually six to twelve months, and water quality is monitored through testing at observation wells before its extraction. The water recovered from the aquifer is almost at drinking water standard (though not by design), and is then used for irrigation in the agricultural areas in the southern part of the country.



SAT soil percolation zone (Source: Mekorot)



SAT recharge basin (Source: Mekorot)

Soil Aquifer Treatment at the Shafdan plant enables the reuse of 130 Million cubic metres of wastewater per year for irrigation purposes, which in turn makes more drinking water standard water available for domestic use, since its agricultural use is avoided. However, after 30 years of operation, the SAT technology has become subject to the following limitations:

- The recharge capacity of the receiving aquifer has deteriorated, because of factors linked mainly to low temperatures and organic matter.
- Bio-film forms inside effluent pipelines, both prior to and following SAT, causing fouling of the pipes.
- The presence of both algal blooms and sand causes clogging of the soil and deteriorates water quality.
- Released manganese and iron oxides, created by anaerobic conditions in parts of the SAT, have caused clogging problems in irrigation systems.
- Finally, and perhaps most importantly, more space is needed in order to increase infiltration and treatment capacity, yet no new land is available given the existing urbanisation trends.

These problems linked to some operational aspects of SAT and to the capacity limitations imposed by existing land availability have led the city of Tel Aviv to explore new innovations in SAT technology which allow for greater infiltration capacity for a given infiltration area.

Modified Soil Aquifer Treatment

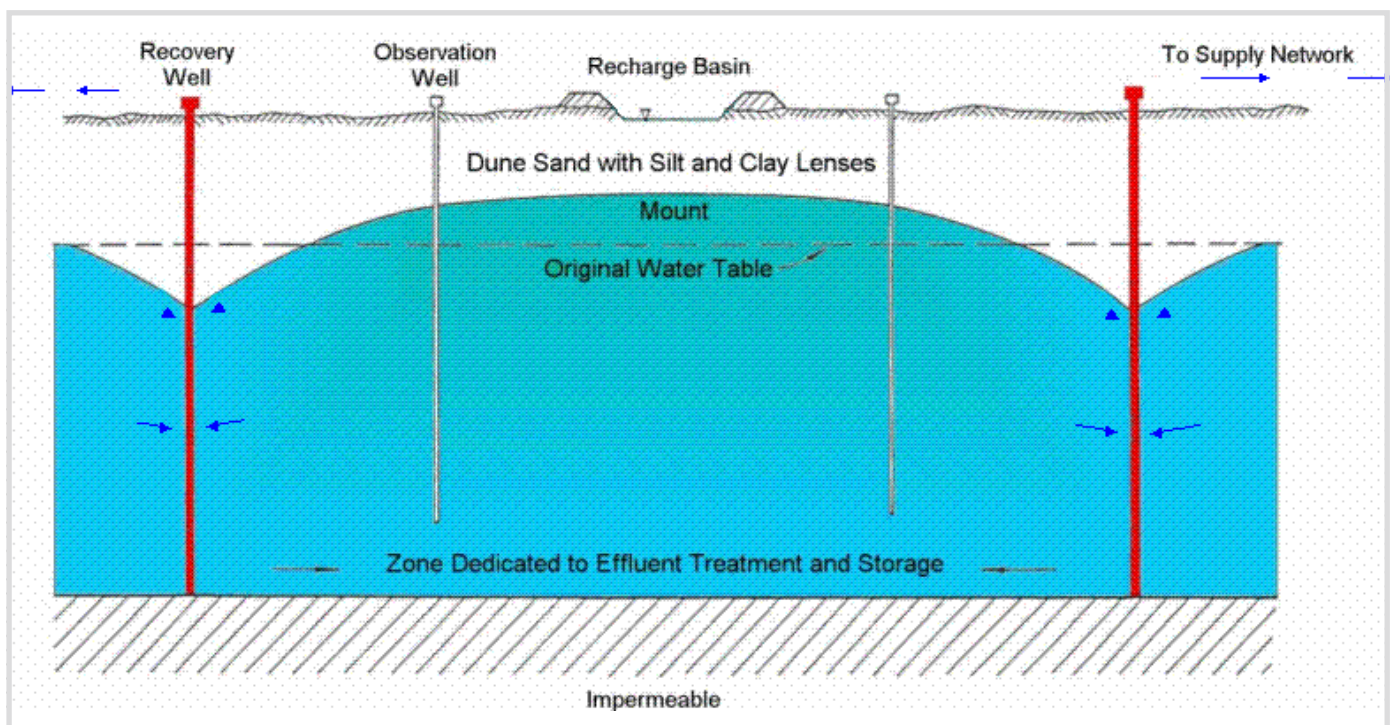
As part of the SWITCH project, Tel Aviv is seeking to produce reclaimed water of the same high quality as that produced by the existing SAT system, while avoiding its pitfalls and limitations. The Shafdan plant started piloting in 2006 'Short SAT-NF' technology, which involves using SAT with drastically reduced retention timescales (typically around 10 days only) for pre-filtration prior to the application of nanofiltration using 0.001–0.008 micron membranes.

In order to assess the efficacy of the new system, the physico-chemical and microbiological characteristics of the reclaimed water were compared to those of the water treated using conventional SAT. They were also compared with the results obtained from another pilot project which used a treatment system beginning with ultrafiltration (UF) and subsequently using SAT with retention times of typically around 30 days.

The modified process addresses the limitations of the conventional technology:

- Pre-treatment of the wastewater using wire then sand filtration of the secondary effluent prior to the SAT drastically reduces clogging of the infiltration field.
- The short SAT process helps minimize the production of proteins and polysaccharides which otherwise leads to clogging of the nanofiltration membranes. Short SAT combined with prior sand filtration not only removes clogging materials, but also reduces dissolved organic matter to levels comparable to the conventional SAT system.
- While the shorter timescales of the SAT (which nonetheless effectively remove microorganisms) cause a reduction in water purification capacity, this is compensated by the highly effective nanofiltration. Chemical parameter test results show that the nanofiltration stage is effective at removing nitrogen and phosphorus, and for organic matter removal is equal or superior to the conventional SAT technology.
- Nanofiltration also effectively removes endocrine disruptors, antibiotics and other micropollutants – this is particularly important given the deleterious impact of these substances on the environment and their increasing presence in wastewater.
- Finally, treatment capacity is increased, as the increased infiltration velocities enable more aquifer recharge. With this system, infiltration rates are three to four times higher than for conventional SAT. The modified SAT technology allows for a reduction in the land area needed for treatment, which makes it advantageous for a growing city such as Tel Aviv.

In sum, the short SAT combined with nanofiltration was found to quickly and efficiently remove microorganisms and micropollutants, producing water of almost drinkable quality very well suited to use for irrigation. This combination of technologies was found to be superior to the conventional SAT technology in terms of land use and time parameters and equivalent in terms of water quality. The process was also found to be superior to the SAT/ultrafiltration combination, which, although it occupies a smaller land area, is relatively more energy intensive and does not remove some micropollutants such as sulfamethaxazole. Moreover, the overall water quality produced by SAT/ultrafiltration is unnecessarily high, particularly in the Tel Aviv context of recovered water use for irrigation rather than direct consumption.



Tel Aviv recharge-recovery scheme (Source: Mekorot)

Lessons learned

The testing undertaken by SWITCH partner Mekorot on behalf of Tel Aviv produced results that will usefully feed into existing research on SAT. In particular, the options tested at the Shafdan plant were assessed not only for their overall efficacy, but also for their efficacy in relation to the intended use of the reclaimed water.

Two different nanofiltration systems were tested; one, NF 90, had tighter membranes than the other, NF 270. Although the tighter membrane system was found to remove micropollutants to a greater degree, the more open membrane system was deemed more economical, because of its reduced energy use and greater water reclamation capacity. The water reclaimed through the NF 270 system is sufficient for the removal of targeted micropollutants in water used for irrigation.

Similarly, the nanofiltration option is better suited to the Israeli context than the ultrafiltration option, even though the latter more effectively removes salt from wastewater. Indeed, policies have decreed that future drinking water requirements will mainly be met through desalination. This means that since the reclaimed wastewater will not be saline, it will dilute salinity in the influent groundwater, and effectively and economically combat the saltwater intrusion into coastal aquifers. Therefore, the need for more expensive ultrafiltration systems is obviated.

The parallel testing of the nanofiltration and ultrafiltration systems also produced important results which inform SAT design. Indeed, since the short SAT removes the extracellular polymeric substances (EPS) that are the primary source of membrane fouling, it is important to run wastewater through SAT prior to any membrane filtration. This is not the case for the ultrafiltration system, which begins with ultrafiltration and ends with SAT, and is therefore subject to membrane clogging.

Wastewater reuse for irrigation in Israel's southern region

Since 1989, Tel Aviv's reclaimed wastewater has been used to irrigate crops in the arid and sparsely populated southern part of Israel, which includes the Negev Desert. The availability of space counterbalances the disadvantages brought about by the climate and the energy required to transport the water from the north, particularly given the political context of the region and the implications this has in terms of food production and water use.

The reclaimed water is used to produce a variety of crops, including vegetables, fruit, grain and flowers, which could otherwise not grow in such arid conditions. The water produced through SAT treatment is supplied to farmers at a reduced price. In 2006 for example, the price per cubic metre of reclaimed water was approximately half of that paid by farmers for freshwater of drinking water quality..



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Replication

Conventional SAT technology is a low cost natural treatment option for wastewater that can be applied in most cities throughout the world, bearing in mind certain constraints. SAT enables the treatment, storage and reuse of wastewater. It is particularly appropriate for water scarce cities where freshwater resources may be overexploited, but also has applications in other cities where treated effluent could become a resource rather than a liability. However, it is important to note that the ultimate reuse purpose of the water, the soil and aquifer characteristics and the quality of the wastewater all influence the effectiveness of the technology and also determine what kind of pre- and post-treatment is needed. This site-specificity requires cities to undertake detailed studies prior to full implementation.

Moreover, as experienced by Tel Aviv, the operation of SAT systems over long timescales can lead to operational difficulties such as clogging, bio-fouling and reduced infiltration capacity. Another constraint is the need for large areas of land for the infiltration basins, land which in many cities is unavailable or unaffordable. The short SAT-NF process piloted in Tel Aviv helps mitigate many of the constraints listed above. It reduces the land surface needed for SAT and increases the treatment capacity of a plant, is subject to fewer operational constraints and finally produces water of a very high quality standard.

Natural wastewater treatment methods

Soil Aquifer Treatment is but one of many existing natural methods for wastewater treatment. Constructed wetlands can mimic the water treatment mechanisms of natural wetlands, and can be used to treat wastewater from a variety of sources and also as a tertiary treatment option for conventional wastewater treatment plants. Wetlands are cost-effective to construct and maintain, and can provide valuable amenity areas as well as increase a city's biodiversity. Another natural treatment option is the use of Waste Stabilisation Ponds (WSP). These are shallow artificial basins that treat wastewater using bacteria and algae in a series of steps. They require regular maintenance and a large surface area, but can be used for aquaculture purposes. Both wetlands and WSPs have very low energy requirements, do not use chemicals, and produce treated effluent that can be used for non-potable purposes. These factors make them cost-effective for cities to operate.



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