Managed aquifer recharge in Finland

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In Finland the selection of the appropriate source(s) of raw water for urban water supply has been debated for more than a century. In rural areas ground water has traditionally been drawn from wells and springs for domestic use, whereby the needs of dairy farming also largely promoted common piped water supplies. The first managed aquifer recharge (MAR) system in Finland was used in Vaasa on the western coast in the late 1920s, and its use was also considered in Helsinki. Yet, the decision by Tampere to give up the ground-water option in 1920 encouraged other cities to use surface water, as ground-water deposits in Finland are generally fairly small. After WWII, surface water was adopted even by cities with available ground-water resources. (Katko 2016, 58)

After the establishment of the National Water Administration in 1970, the use of ground water became predominant, and around the same time, wider use of MAR started. In spite of its many advantages the use of ground water for community water supply is no longer automatically considered the best option, since the current aim is to keep all water sources as clean as possible. The debate between surface and ground-water use seems, however, to continue. (Katko 2016, 58)

By the 1960s and 1970s surface water had often become polluted, but efficient water pollution control and wastewater treatment have improved its quality dramatically. Yet, Finnish waters contain natural organic matter (NOM; humus) and are also soft, since the bedrock contains only a little calcium. Therefore, surface water needs more complicated treatment, often chemical, to meet domestic water quality requirements. (Katko 2016, 59)

During the last few decades, Finnish community water supply has increasingly relied on natural ground water and MAR as raw water source (Table 1). Currently, their combined share of the water supplied is some 67%. The share of MAR alone is roughly 17 %, including bank filtration. However, potential ground-water areas and places for ground-water recharge are sparsely situated. Thus, large city centres, with their increasing need for fresh water supply, are obliged to withdraw ground water from afar, often crossing municipal borders. (Katko, 2016)

The main objective of MAR in Finland is the removal of NOM from surface waters. A typical MAR procedure consists of the infiltration of surface water into an esker with subsequent withdrawal of the MAR-treated water from wells a few hundred meters down-gradient. The infiltrated water should have a residence time of at least approximately one month before withdrawal to provide sufficient time for the subsurface processes needed to break down or remove humic substances.

There are currently 26 MAR plants in Finland and, in addition, a few plants are being planned. The MAR plants are operated continuously, also during winter. Basin infiltration is used most often, whereas sprinkling infiltration was initiated in the mid-1990s. Sprinkling infiltration includes an aboveground pipe network through which water is distributed on top of natural forest soil. Well infiltration or well injection is applied only in a couple of MAR plants in Finland. However, new infiltration wells are being planned and tested. (Jokela & Kallio 2015)

Table 1. History of MAR in Finland (approximate values)
Raw water is taken from lakes and rivers.

Period	MAR production (10^6 m^3/a)	Infiltration methods
1961 - 1970	< 1	basin (the first MAR plant started in 1970)
1971 - 1980	30	basin, dug well, bank
1981 - 1990	35	basin, dug well, bank
1991 - 2000	50	basin, sprinkling, dug well, bank
2000 - 2010	55	basin, sprinkling, well, bank
2011 - 2015	65	basin, sprinkling, well, bank (share < 10 %)

Most of the Finnish MAR plants do not have pretreatment and raw water is infiltrated directly into the soil. During a MAR process in an unconfined esker aquifer NOM is removed by physical, chemical, and microbial processes. Most of the NOM removal takes place in the saturated ground-water zone.

Most often, total organic carbon (TOC) concentrations of the raw waters vary roughly from 6.5 to 11 mg/L and after MAR the TOC concentrations of the abstracted waters are approximately 2 mg/L. The overall reduction of organic matter in the treatment (with or without pretreatment) is thus 70–85% (Jokela et al. 2017).

Mechanical pretreatment can be used for clogging prevention. Turbidity of the Finnish lakes used as raw water does not necessitate pretreatment in basin and sprinkling infiltration, however, pretreatment in well infiltration needs to be judged separately. River waters may have high turbidity requiring pretreatment. Natural conditions in esker aquifers are generally aerobic. Biodegradation of NOM in the saturated ground-water zone consumes dissolved oxygen. The higher the NOM content, the higher the dissolved oxygen consumption. If dissolved oxygen concentration in the ground-water zone sinks low enough, conditions for dissolution of iron and manganese from the soil increase. Iron and manganese dissolution may be avoided by the addition of chemical pretreatment for the raw water to cut the NOM content. According to the results from selected MAR plants, raw waters with TOC content up to at least approximately 8 mg/L are infiltrated without any considerations of chemical pretreatment. A higher share of natural ground water provides more dissolved oxygen. However, aquifer properties, including the soil composition, vary locally and have influence on the MAR process. (Jokela et al. 2017)

Eskers in Finland are glaciofluvial formations which were commonly deposited by streams in tunnels beneath the ice during the final deglaciation of the Scandinavian ice sheet. Typically, an esker consists of 20 to 50 m of gravel and sand that is covered by a thin humic soil layer (<10 cm). Eskers are preferred areas for potable water MAR treatment. However, they can also be centers of population, considered recreational areas or nature conservation sites, or they can be sources for extraction of gravel. When MAR plants are being planned, these interests may conflict. Public participation is an important feature of MAR planning in Finland (Jokela & Valtonen 2010, Kurki & Katko 2015). Sprinkling infiltration and well infiltration can be attractive for areas not suitable for the construction of basins, e.g., eskers with slopes, and forest areas having recreational values with restrictions on tree cutting. When sprinkling infiltration or well infiltration is used, there is no need to dig and construct basins and direct physical effects on the landscape are reduced. Recreational values, including minimizing the effects on landscape, are often emphasized in public participation.

Recycled water is not used at Finnish MAR plants. The MAR process removes pathogens efficiently, both bacteria and viruses. Risks of contamination of the recharge process are reduced by the choice of good quality raw waters and protection of the recharge areas from external, possibly harmful activities (such as gravel extraction or handling of petroleum). Before distribution to the trunk mains, water is disinfected by ultraviolet (UV) radiation, chlorination, or both, and, when necessary, the alkalinity and hardness are adjusted.

However, conventional ground-water management approaches, drawing from expert-based instrumental rationality, seem often to be insufficient for successful project planning and implementation. Based on an exhaustive study on two large MAR projects in Finland, Kurki (2016) suggested that in ground-water governance the core should be in collaborative rationality while some of the tools can be obtained from rationalistic expert-based planning. Thereby project legitimacy should be gained through joint knowledge production as well as interaction where addressing stakeholders' interests could help in finding mutual gains and new options for collaboration (Kurki & Katko 2015). Thus, water experts should be more facilitators rather than holders of the only legitimate source of knowledge, and the stakeholders like partners rather than informants.

References

Jokela, P. and Kallio, E. 2015. Sprinkling and well infiltration in managed aquifer recharge for drinking water quality improvement in Finland. J. Hydrol. Eng. 2015, 20, 3, B4014002-1 - B4014002-7, DOI: 10.1061/(ASCE)HE.1943-5584.0000975.

Jokela, P. and Valtonen, J. 2010. Managed aquifer recharge and public participation. In: Proceedings of the 7th international symposium on managed aquifer recharge (ISMAR7), Abu Dhabi, October 9 – 13, 2010, 461-468.

Jokela, P., Eskola, T., Heinonen, T., Tanttu, U., Tyrväinen, J. and Artimo, A. 2017. Raw water quality and pretreatment in managed aquifer recharge for drinking water production in Finland. Water 2017, 9, 138; doi:10.3390/w9020138.

Katko T. S. 2016. Continuous Debate: Selection of Appropriate Raw Water Source. pp. 58-67. In: Finnish Water Services – Experiences in Global Perspective. Finnish Water Utilities Association. 288 p. www.finnishwaterservices.fi

Kurki V. 2016. Negotiating Groundwater Governance: Lessons from Contentious Aquifer Recharge Projects. Doctoral dissertation no. 138, Tampere University of Technology. https://tutcris.tut.fi/portal/files/6149146/Kurki_1387.pdf

Kurki V. and Katko T. S. 2015. Groundwater as a source of conflict and cooperation: towards creating mutual gains. Water Alternatives. 8,3: 337-351. http://www.wateralternatives.org/index.php/alldoc/articles/vol8/v8issue3/295-a8-3-3/file