Managed aquifer recharge (MAR) in Jordan

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Managed aquifer recharge (MAR) has been practiced in Jordan since the 1960s and is firmly anchored in the national water strategy (MWI 2016) with the main goal to augment groundwater availability. Schemes for flood water recharge have been implemented and treated wastewater is proposed to be used in the future. However, the latter is only allowed to be recharged to aquifers that are intended for irrigation and not for drinking water purposes. In such cases, the use of reclaimed water for MAR is controlled by the standard regulations and legislations (MWI 2001) which preset the maximum concentration for diverse parameters. Further considerations by the Ministry of Water and Irrigation (MWI) may adapt these standards in order to achieve a more flexible approach for individual MAR sites, e.g. to allow the recharge of less treated wastewater to aquifers of poor quality that are still suitable for irrigation purposes (MWI 2001).

MAR is mainly performed using percolation reservoirs, recharge and release dams, and by injection wells (Xanke *et al.* 2015), both into alluvial deposits and limestone aquifers. In some cases, the reservoirs showed high infiltration rates despite being constructed with the primary purpose of surface storage (e.g. Shueib dam, Kafrein dam). However, heavy sediment loads, as a result of the sparse soil cover in these desert catchments, reduce the life span of many of the reservoirs by causing a loss of the storage capacity and a reduction in infiltration rates. As yet there are no applicable solutions to avoid the sedimentation. There is also a high risk that the outlets of the recharge and release facilities, such as at Wala dam, may become blocked by sediments. This has occurred for some conventional dams between the early 1960s and the early 1990s (Steinel 2012).

Table 1 List of dams in Jordan used for MAR (modified after Steinel 2012; Riepl 2013; Hadadin 2015; Xanke *et al.* 2015).

Location	Period of operation	Mean annual infiltration (MCM)	Initial and current storage capacity (MCM)	Geological formation (labeling)	MAR techniques/ Comment
Wala dam	2002 - today	*6.7	9.3/7.7	Limestone (A7)	percolation reservoir, injection wells
Shueib dam	1968 - today	**0.7	2.5/1.43	Alluvial deposits	percolation reservoir
Kafrein dam	1968 - today	n.a.	8.5/6.0	Alluvial deposits	percolation reservoir
Wadi Madoneh	2003 - today	n.a.	0.09	Limestone (A7)	4 recharge and release dams
Wadi Butum	2011 - today	n.a.	0.47	Limestone (B4)	3 percolation reservoirs
Sultani dam	1962 - n.a.	n.a.	1.2	Limestone (B2/A7)	percolation reservoir/clogged
Qatrana dam	1964 - n.a.	n.a.	4	Limestone (B2/A7)	percolation reservoir/clogged
Rajil dam	1992 - n.a.	n.a.	3.5	Limestone (B4/B5)	percolation reservoir/clogged
Siwaqa dam	1993 - n.a.	n.a.	2.5	Limestone (B2/A7)	percolation reservoir/clogged

*2002-2012; **2001-2009

A successful example of MAR is the Wala reservoir, where about 6.7 MCM/a, on average, infiltrate into the underlying karst aquifer. The water is abstracted at the 7 km downstream Hidan wellfield and contributes about 11.7 MCM/a, on average, to the drinking water supply of Jordan's capital Amman, Madaba city and smaller communities in the immediate surroundings (Xanke *et al.* 2015). Further comprehensive hydraulic and numerical studies have been done by Xanke *et al.* (2016), which revealed a decrease of the mean groundwater table on the long-term as a result of accumulating sediment in the reservoir and the associated reduction in the infiltration rate. In the case of the Kafrein and Shueib dams, the natural seepage from the reservoirs augment groundwater availability for irrigation purposes in the Jordan Valley, but only the water balances of the Shueib dam has been calculated by Riepl (2013) to be about 0.4 MCM/a in average. However, in the most cases the recharge rates are not well documented.

Further research in Jordan is commissioned by the MWI (Steinel *et al.* 2016) to evaluate the potential of MAR in porous aquifers (Steinel 2012).

Literature

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