## Managed aquifer recharge in Italy

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Italy has a long history of managing aquifer recharge. In Venezia, man-made water-banking of rainfall in the soil dates back to the end of the middle-age as the main source of drinking water (Vanzan Marchini, 2009). Rainwater was harvested and then conveyed to city "squares" (*campi*). These were filled with sand and stored all the harvested water that then drained through the sand medium to supply a large well (with its characteristic "*vera*") in the middle of the square. There is also substantial recharge enhancement from traditional means such as river weirs and wells near the embankments of surface water bodies. These techniques are detailed in M. Canavari Engineering Geology Primer (1928). Unintentional incidental enhanced recharge through excess irrigation also occurs as elsewhere in the world. However, in the last 60 years other forms of intentional artificial recharge in Italy have occurred only at experimental or demonstration level. Since 1969, 40 experimental pilots have been established, but not yet made a major contribution to water supply. So, it may be said that in spite of the long history in some locations, aside from riverbank filtration, managed aquifer recharge in Italy is still in its early stage of development.

While in Italy water scarcity is a major issue in the southern part of the country, the bulk of the pilots are located in the northern area (Fig. 1). The aim of these pilots is to maximize natural storage in aquifers, combat saltwater intrusion and to improve water quality. Infiltration ponds comprise the most widespread method followed by dry wells, with Forested Infiltration Areas being the most innovative type. These are rural areas where farmers store water while growing trees (for wood production), by using irrigation channels during the non-irrigation season. However, Induced River Bank Filtration (IRBF) is by far the largest managed aquifer recharge scheme currently used, even though it is not widely recognized as such, and the hydraulic connection between the surface water body and the aquifer is often disregarded by practitioners and technicians in governing authorities. It is crudely estimated that more than 400 $Mm^3$ of drinking water is supplied from IRBF wells. This estimate is based on the assumptions that IRBF schemes exist at rivers where average yearly discharge is higher than 30 $m^3/s$ and that an average of 10 $Mm^3$ per scheme are then used.

Since the beginning of 2010, some projects on managed aquifer recharge were co-financed by the European Commission mainly through the LIFE program (TRUST - Tool for regional - scale assessment of groundwater storage improvement in adaptation to climate change (Marsala 2014); AQUOR - Implementation of a water saving and artificial recharging participated strategy for the quantitative groundwater layer rebalance of the upper Vicenza's plain (Mezzalira *et al.* 2014); WARBO - Water re-born - artificial recharge: innovative technologies for the sustainable management of water resources; Nieto Yabar *et al.*, 2012).

Nearly all of them, use the terminology of artificial recharge instead of MAR. The evolution of MAR capacity in Italy is shown in Table 1.

In 2014, the Regional Authority of Emilia Romagna started a pilot on the Marecchia River fan to alleviate water scarcity in the Rimini area resulting from recurrent drought periods (Severi *et al*. 2014) using a recharge basin. The pilot was terminated two years later after having recharged about 2 $Mm^3$ while currently awaiting permitting of the full-scale plant.

One of the main characteristics of these pilots is that they are focused on site characterization, investigation and hydrodynamics issues, while little attention is generally paid to water quality aspects. In many cases, a very small number of piezometers (in some cases only one) are set in place in order to monitor recharge effects. This is a critical point, and unless addressed has potential to turn public perception of MAR from an opportunity to a threat to ground-water. Within the EU FP7-ENV-2013 MARSOL project (Demonstrating Managed Aquifer Recharge as a Solution to Water Scarcity and Drought; www.marsol.eu), a dedicated focus was posed on water quality issues at the 15 $Mm^3$/year IRBF plant in Sant'Alessio (Rossetto *et al*. 2015), demonstrating that IRBF may constitute a reliable (when care is paid to water quality aspects) and important source of water.

Table 1. Evolution of MAR in Italy

| Decade | Induced River Bank Filtration ($Mm^3$/yr) | Other forms of MAR ($Mm^3$/yr) | Total ($Mm^3$/yr) |
|---|---|---|---|
| 1961-1970 | 172 | 6 | 178 |
| 1971-1980 | 258 | 36 | 294 |
| 1981-1990 | 301 | 0 | 301 |
| 1991-2000 | 344 | 4 | 348 |
| 2001-2010 | 387 | 4 | 391 |
| 2011-2015 | 430 | 31 | 461 |

IRBM are estimated values only, based on population growth. Other forms of MAR values are derived from cited reports. This represents about 8% of total domestic water supply in Italy in 2012 (5000$Mm^3$/yr).

The main barrier to development of aquifer recharge in Italy has been until 2016 the lack of a piece of legislation on licensing MAR plants. While recharge of aquifers has been allowed since September 2013, as foreseen by the EU Water Framework Directive (EU, 2000), the regulation on licensing and permitting MAR plant (*impianti di ricarica della falda in condizioni controllate*) was promulgated only in June 2016 (DM 100/2016). This piece of legislation strongly focuses on monitoring issues, especially regarding water quality. The above-mentioned Emilia Romagna MAR plant, following the permitting application, is now under consideration to become the first Italian operational MAR scheme conforming to this framework. A new MAR pilot is under development within the EU LIFE REWAT (sustainable WATer management in the lower Cornia valley through demand REduction, aquifer REcharge and river Restoration) in Tuscany.

So far, there is growing interest in this low-cost, potentially low-energy technique, as it may constitute a valid alternative to traditional water treatment or allow conjunctive management of surface-water and ground-water bodies. At the same time, lack of knowledge at the level of intermediate governing bodies, as well as among professionals, is preventing the application of these techniques. For example, MAR plants, even though more economic and environmentally benign, are overlooked in favour of building of small surface water reservoirs. Therefore, dissemination of MAR scientific findings and technical know-how among governing authorities and the general public is crucial for the application of MAR techniques.

Finally, it is of utmost importance to identify the financial instruments to set up and sustain these water infrastructures, so as to guarantee routine operations and maintenance, and thereby opening a new market in the water sector.

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Figure 1. Locations of MAR experimental sites in Italy