The Effect of Tube Recharge on Local Groundwater Tables and Well Water Levels.

Context

The Earth's fresh water reserve amounts to less than 3% of all water on the planet. Around 30% of this fresh water is contained in groundwater reserves in shallow and deep aquifers (USGS, 2018). Groundwater represents more than 95% of the world's "useable" fresh water. Around 50% of the global population depends on groundwater for their drinking water supply, and 43% of all water for irrigation also comes from groundwater (WWAP, 2015).

Groundwater use has been part of human life for millennia. The steep rise in population and water demand in recent years has dramatically increased groundwater use. Worldwide, 2.5 billion people depend solely on groundwater resources to satisfy their daily water needs (UNESCO, 2012). In many areas, for example in India, the rate of abstraction has by far exceeded the natural recharge rate, resulting in a lower water table and the depletion of limited groundwater stores (Kaledhonkar, Singh, & Ambast, 2003; Wada et al., 2010). In addition, climate change has altered rainfall patterns all over

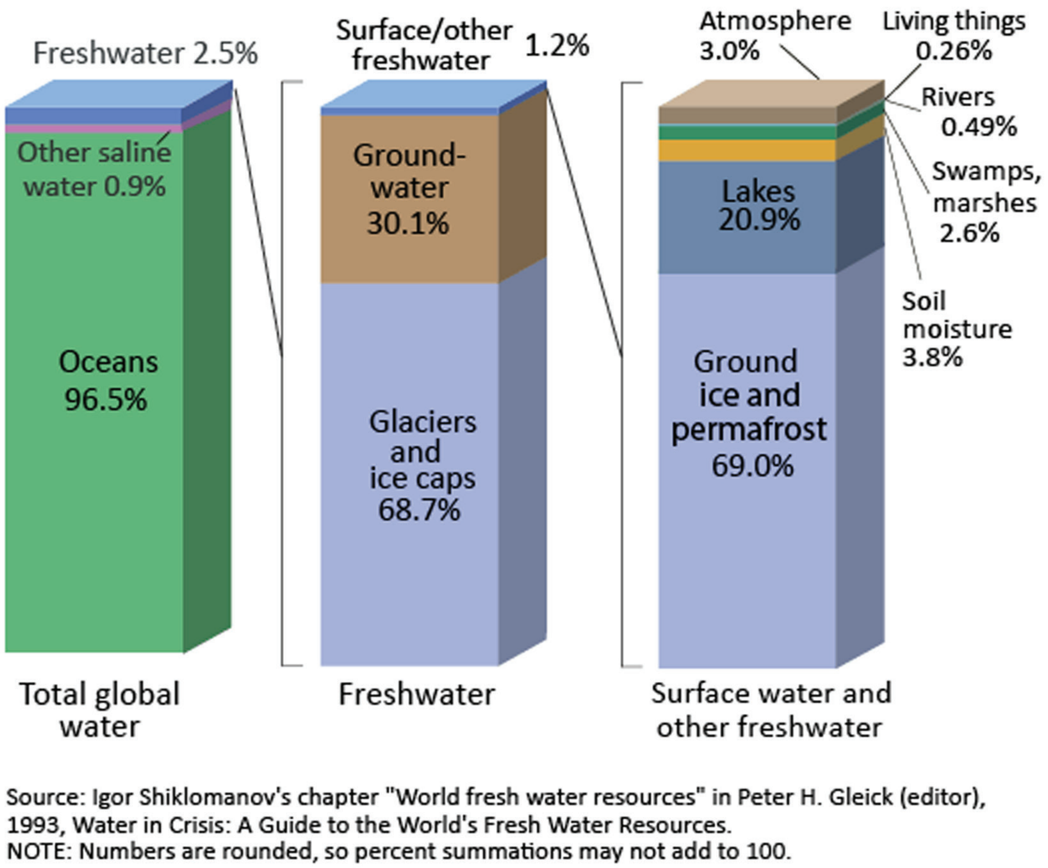


Figure 1. Global water distribution (Source: water.usgs.gov)

the world. In certain areas, rainfall events are more intense and happen in a short time span, making it difficult for water to infiltrate the ground. The effects of climate change are exacerbated by land use changes resulting in impervious surfaces that significantly limit natural infiltration.

Groundwater is a finite resource that needs to be used sustainably and replenished constantly to offset the effects of abstraction. The process by which water percolates into the ground replenishing groundwater stored in aquifers is called groundwater recharge. Groundwater recharge can be a natural or artificial process. The rate of groundwater recharge depends on the type of soil and the depth of the aquifer. Recharge can be fast in sandy soil, but natural groundwater recharge by way of the water cycle is generally a slow process. Given the spike in groundwater abstraction and the slow rate of natural recharge, it is necessary to augment natural groundwater recharge with artificial mechanisms to sustain groundwater reserves. Groundwater recharge is also a cost-effective method of water harvesting, as storing water in the ground is the cheapest way to capture rainwater. This is especially important in water-scarce developing countries.

Artificial groundwater recharge is a process through which groundwater is replenished at a rate that is much higher than the natural recharge rate. Artificial recharge occurs either directly or indirectly through surface and subsurface recharge. Figure 2 shows the range of alternatives available for artificial groundwater recharge. Some of the recharge techniques are largescale, technical, and costly, while others are simple and can be implemented at the household level.

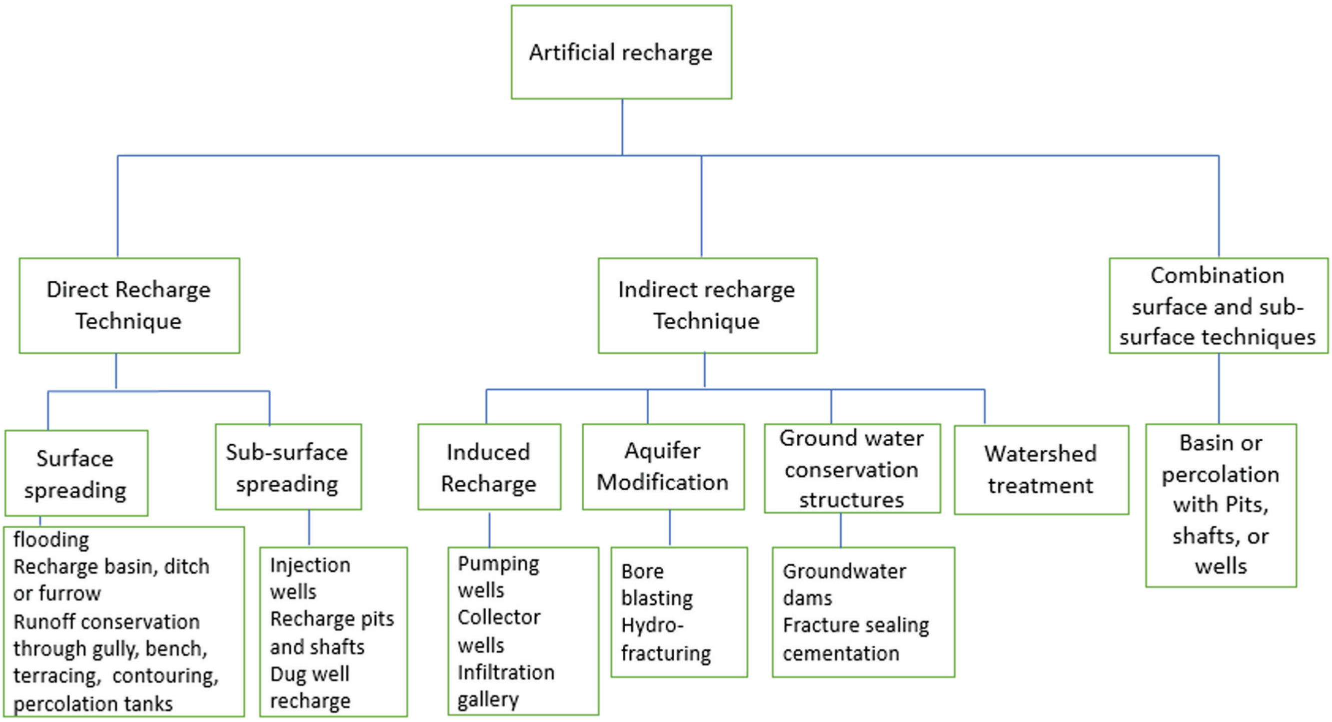


Figure 2. Categories of recharge methods (Tredoux, Murray, & Cave, 2002)

Tube recharge systems

The Tube recharge system is a simple method of artificially recharging groundwater at the household level. It is a low-cost technology that allows rainwater that would otherwise evaporate or run off to percolate into the ground and replenish aquifers. It is especially useful in locations with a compact topsoil layer that rainwater cannot easily infiltrate. The Tube recharge method allows water to bypass this compact layer and inject water into a more permeable stratum. The fact that Tube recharge is a simple and low-cost method makes it appealing for household applications.

Why a Tube recharge system?

Tube recharge is especially advantageous as a local groundwater recharge method, because:

- It does not require a lot of land;
- There is no transit or evaporation loss, as water directly flows into the permeable soil layer to recharge the aquifer;
- It is a relatively fast way to recharge groundwater, especially for shallow aquifers
- Its effect can be easily observed if installed near wells that dry up, as it can prevent well drying and even revive dried up wells;
- It is a very low-cost method that can be implemented with locally available materials and labor.

Tube recharge systems can be easily installed in places like topographical depressions, abandoned canals, and canal escapes where excess surface runoff either accumulates or is conveyed for disposal. Tube recharge systems are constructed by embedding a PVC tube in a manually dug hole upstream of an active or dry well. Rainwater collects in the hand dug basin and is allowed to settle. The collected water then percolates through a series of natural filters of gravel and sand before passing through the PVC pipe into the soil above the aquifer. The total cost of Tube recharge construction usually ranges between 10-100 USD, depending on the material used and the cost of labor. It is possible to recharge an aquifer with 2-10m^3 of water from a single rainfall event , totaling to 100-500 m^3 per rainy season depending on the size of the basin (Netherlands Water Partnership, 2007). The series of figures below show the construction of a Tube recharge system.

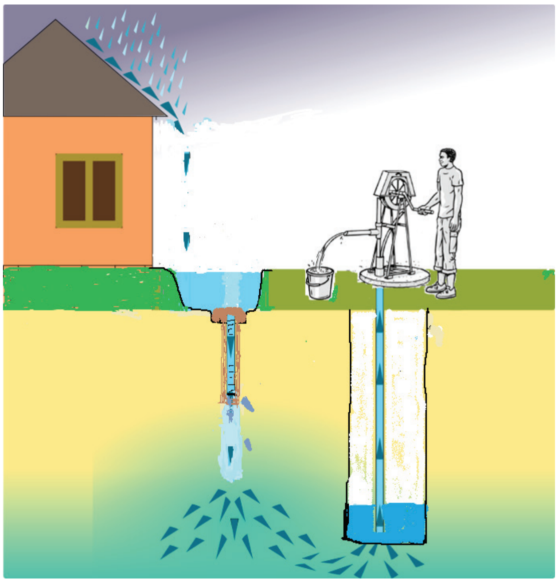
After making a pit, a filtration hole is made with a soil punch. The size of the pit depends on the location, but it can between 1 and 10 m^3. For greatest effect, a Tube recharge system should be installed 5 to 10 meters away from wells that dry up in the dry season.

The recharge hole should pass the top compact layer; in this case, it is 6 m deep. Then the sand filter pit is made and the injection hole is filled up with course sand or gravel to 30 cm from the top.

A ¾" PVC pipe that is 3 m long with filter slots at both ends is placed in the hole. The top of the pipe should be closed and be 10 cm under the sand. The hole is then filled with gravel and the sand filter pit is filled with sand.

The sand is covered with a cloth filter folded around a metal ring made of 10 mm round bar. Bricks are placed on top to prevent the cloth from floating. A rope is attached to the sand filter to facilitate the removal of the cloth filter for cleaning.

This pit has a catchment area of 200m². When it rains, the pit fills up. After some hours, the water infiltrates the ground via the cloth and sand filters. This is repeated every time it rains.



In this case, Tube recharge is combined with the roof water harvesting technique. The gutter from the roof can be connected to a pit or a tank where rainwater from roofs can collect and infiltrate the ground.

Because the runoff water is dirty, the cloth filter gets clogged and has to be cleaned regularly.

Material cost of this Tube recharge is 10 USD.

It takes 2 to 4 working days to dig the pit and the hole.

Figure 3. Tube recharge in the making (Source: SHIPO (Southern Highlands Participatory Organization) model, Tanzania SMART center, Henk Holtslag)

Experience with recharge systems

The theory of artificial recharge methods has been extensively studied, and the expected impact on the local groundwater level has been modeled and well documented. However, we have not found quantitative studies regarding the effects of Tube recharge systems on groundwater tables. It is possible to measure how much water infiltrates the ground using a Tube recharge system, but it is difficult to measure how much water is going to the well and how much is flowing away. The only way to measure the effect of Tube recharge is to compare well water levels in wells with and without Tube recharge systems in place in the same area and under the same climatic conditions (Personal communication, Henk Holtslag, 2017). This has not been done yet, but ECODES, an organization in Nicaragua, is exploring these kinds of measurement efforts.

Nevertheless, anecdotal evidence from case studies in various regions of the world have shown that groundwater recharge is effective and enhances the groundwater storage. Olanker (1981) states that the development of groundwater recharge through wells, tube wells, and reservoirs may result in a regular increase of the water table (Patel, Rank, Ajudiya, & Dhanani, 2014).

Pilot projects in Ghana, Tanzania, Zimbabwe, and Zambia have demonstrated that Tube recharge systems work well. Families using Tube recharge systems had water in their wells throughout the year in places where wells would normally dry up for 2-4 months (Knoop, Sambalino & Steenbergen, 2012).

In Mozambique, a water and sanitation NGO called Grupo de Saneamento de Bilibiza (GSB) facilitated the installation of 100 Tube recharge systems in Quirimba National Park where more than 140,000 people live. The recharge systems that are managed and regularly maintained are working perfectly, and wells nearby have water all year round. Previously, these same wells would be dry from September until the beginning of the rainy season in December (Personal communication, Bachir Afonso, 2017).

In Nicaragua, ECODES has installed more than 180 Tube recharge systems and has received “excellent” feedback from users. Some 150 systems are functioning well, and some families have even started copying the system without the support of ECODES (Personal communication, Nienke Swagemakers, 2017).

A system similar to Tube recharge is a recharge pit. An experiment on artificial recharge through recharge pits was conducted in Dabhu, in the central Mehsana region in India. This experiment showed that a recharge pit measuring 1.7 m x 1.7 m x 0.75 m saw a recharge rate of 17.3 m^3/day with an infiltration of 0.5 m/day after 60 days. An increase of 4.13 m in water level was observed in wells at a distance of 5 m from the recharge pit (Central Groundwater Board, 2000).

Stories of improved farm productivity are reported where recharge pits are implemented. For instance, a farmer in India was able to revive his dried up well with a recharge pit of 3m x 3m x 3m. Despite living in one of the driest areas in India, this farmer grows bananas, maize, jasmine, coconut, ragi, cotton, chrysanthemum, and other crops on his 23 acres of land. He also grows areca nut along with banana through the intercropping method. Areca nut is a very water-intensive crop requiring 5 liters of water per plant every other day. This farmer has 3,400 areca nut plants and 2,400 banana plants in his field. The farmer testifies that this change was possible owing to the revival of his dried wells through pit recharge.[1]

Although there is limited scientific research concerning the performance and effectiveness of Tube recharge, anecdotal evidence shows that there is a visible increase in well water levels. In some places in India, Tube recharge systems have increased well outputs three to six times.[2] Completely dried up wells have been revived through this method. Recharge also enhances the quality of groundwater. It reduces salinity and water hardness, as the recharging occurs by rainwater.

Tube recharge has proven to be a cost-effective, long-term solution for capturing rainwater. According to an Indian study, Tube recharge costs one-fifth the amount required to build a new tube well, which is usually the cheapest means of providing water.

The Tube recharge system can be customized to meet the demands of farmers and local conditions. They provide a permanent solution to water scarcity that is applicable at the household level. Recharged wells can meet agricultural water requirements, increasing irrigation potential and enhancing crop diversity and crop cycle. This eventually leads to higher yields and improvements to farmers' livelihoods.

Points to Note

The Tube recharge system is a simple technology, but several critical details should be considered to ensure its effectiveness; simple does not mean easy. Like any technology, a Tube recharge system has to be made well if it is to function well (Personal communication, Henk Holtslag, 2017). Here are some points to note on Tube recharge construction and use:

1. Tube recharge systems should only be installed in areas where all or part of the rainwater runs off into rivers or evaporates. In areas with highly permeable soil, like sandy soil, Tube recharge does not add value, as water can naturally infiltrate the ground.
2. Care must be given to water quality in recharge. Rainwater is naturally sterile; however, if contaminated runoff reaches the retention pit, it could result in large-scale and irreversible groundwater pollution—one of the last sources of unpolluted water ("Research news," 2003). To mitigate the threat of groundwater contamination, three measures are adopted in places where Tube recharge is employed:
    - Tube recharge systems should always be constructed at least 5m away from water wells. This ensures that there is at least 5m of soil between the recharge pit and the well. The soil functions as a filter before the water reaches the well.

1. http://www.indiawaterportal.org/articles/battling-water-scarcity-borewell-recharge
2. https://www.changemakers.com/BCideas/entries/tube-well-recharge

- Water from Tube recharge should not be injected directly into the well. The recharge hole of a Tube recharge system stops at least 3 m above the aquifer. This ensures that water seeping from the Tube recharge system can be filtered by 3m of soil before reaching the acquifer.
- Water coming from Tube recharge should be treated at the household level when used for drinking. Water treatment methods such as chlorination, boiling, and household tabletop water filters ensure the safety of well users in the unlikely event of well contamination. (Personal communication, Henk Holtslag, 2017).

3. Tube recharge should be augmented with eco-friendly water conservation and watershed treatment developments such as reforestation, contour dams, and vetiver grass dams for holistic and sustainable outcomes in the long term.
4. The functionality of Tube recharge systems also depend, to a large extent, on the upkeep of recharge pits. Experience from Mozambique shows that if recharge pits are not cleaned after every rainfall, the retention pit clogs up and the system will not work (Personal communication, Bachir Afonso, 2017).
5. The effect of the Tube recharge is long term and can only be seen after one or two rainy seasons.

An estimated 50% of some 4 million hand dug wells in Africa dry at the end of the dry season. Tube recharge and other recharge technologies have the potential to mitigate the effectssuch issues of climate changewater availability. However, it takes time to change people's mindsets and engage them in a new endavor. It is only after seeing how a new technology can benefit them that families and communities commit to the upkeep of the infrastructre. Short-term projects cannot impart such effects on communities. To achieve such sentiments in local communities, there needs to be a "critical mass" to demonstrate how the technology works and its benefits for the community. Experts recommend that 5% of the families in a community need to have a workingwell functioning system to demonstrate its benefits so that other families can invest in it.

Long-term projects that invest in training, maintenance, and follow-up are necessary to reap the full benefit of such technologies. Experience has shown that tubeTube recharge works best at the family level, as this promotes a feeling of ownership. Families, more than communities, are committed to investing and keeping up a system that benefits them. Given the success rate of the tubeTube recharge system, it would be of siginificant value if largescale experiments were undertaken to quantify the effectiveness of the system, adding to the anecdotal evidence described in this paper.

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Personal Communications

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2. Henk Holstlag from the Netherlands, SMART Centres Coordinator, Interview, 2017
3. Nienke Swagemakers from ECODES, email communication, 2017.

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