Cumulative rainfall collectors – A tool for assessing groundwater recharge

JMC Weaver[1] and AS Talma[2*]
[1]*Groundwater Group, Environmentek, CSIR, South Africa*
[2]*Quaternary Dating Research Unit, Environmentek, CSIR, South Africa*

Abstract

The great majority of Southern African aquifers depend on rainfall for their recharge. The accurate estimation of recharge remains one of the biggest challenges for groundwater investigators. Accurate recharge estimations are needed for proper groundwater management as this governs the estimation of sustainable exploitation. Current estimates of recharge to aquifers range between 0.2 and 3% of annual rainfall for the drier Karoo and Kalahari areas and up to 20% for the winter rainfall region of the Western Cape. Important input for determining recharge is knowledge of the chemical and isotopic composition of rainfall. This paper describes a simple, low-cost and low-maintenance tool, the cumulative rainfall collector (CRC), which provides a cumulative sample of rainfall which is unaffected by evaporation. The instrument is capable of collecting rainfall over periods of up to one year. The crucial aspect is to store sufficient rainfall, to eliminate evaporation by covering the water sample with silicon oil and to reduce interference by birds.

CRCs were installed at Struisbaai, the West Coast and the South Coast of the Western Cape Province. CRC data for Struisbaai indicate that recharge to the Table Mountain Group (TMG) Aquifer is 17.4% of mean annual rainfall. The West Coast transect includes two production wellfields. CRC data indicate that recharge is 9.7% to 13.5% for the Bredasdorp Formation of the Langebaan Road Wellfield. At Agter Witzenberg recharge estimations range from 24% to 46% to the Nardouw Formation of the TMG. The South Coast transect encompasses the Klein Karoo Rural Water Supply Scheme and CRC data indicate that recharge to the Peninsula Formation of the TMG is 5%.

Keywords: Groundwater recharge, rainfall quality, cumulative rainfall collectors, TMG aquifer, Bredasdorp aquifer, chloride mass balance, deuterium displacement

Introduction

The need for regular rainfall sampling has been known for many decades. The recognition that acid constituents in rain arising from air pollution present a danger to ecosystems and to humans has necessitated large rainfall sampling networks on global and regional scales in which the emphasis is on rainfall chemistry. The atmospheric nuclear weapon tests of the 1950s triggered a global network for the collection of rainfall samples for tritium and stable isotope analysis (see IAEA-GNIP website) that has become useful for many disciplines. Groundwater professionals have started to use chemical and isotopic properties of rainfall as input to the groundwater system. The data enable estimates of recharge to be made.

The standard rainfall sampling protocols require that rainfall be collected at least daily and the samples immediately analysed or stored for some sort of cumulating procedure. This is a time consuming manual effort and automation is quite expensive to make it reliable enough. Sophisticated samplers have been designed that collect separate rainfalls and also separate dry and wet deposition. These are expensive to purchase and maintain and require power. Groundwater professionals are usually interested in cumulative data (seasonal or annual) and prefer a spread of localities to identify regional effects. Using the standard sampling protocols when annual data are sufficient, is therefore superfluous and uneconomic. There is therefore a need for a simple cumulating rainfall sampler that can operate for long periods without supervision.

* To whom all correspondence should be addressed.
☎ +2712 841-3402; fax: +2712 349-1170;
e-mail: stalma@csir.co.za
Received 20 October 2004; accepted in revised form 18 March 2005.

Previous work

Friedman et al. (1992) collected integrated samples over a 7-year period in the south-east California desert at elevations ranging from below sea-level to 2 280 m. Their sample collectors were constructed from white polypropylene and rubber tubing. They were able to use the results to distinguish between the origin of winter and summer precipitation. The collector bottles had a layer of hydrocarbon oil to prevent evaporation of the water. A gelatinous third phase developed, resulting in an under-estimation of rain volume; however, analysis showed that this phase had the same deuterium value as the rain, and thus did not alter the deuterium content of the water. They did not carry out chloride analyses and did not do recharge calculations. This work is the first design of a rain collector that used an oil layer to reduce evaporation.

Scholl et al. (1996) used precipitation and groundwater isotope data to interpret the regional hydrology on Hawaii. They used CRCs to obtain the chloride and isotope signature of precipitation. Initially they used a 3 to 4 mm layer of oil but found that significant evaporation occurred from both indoor and field controls. Field controls showed weight losses of 0 to 33‰, and $\delta^{18}O$ enrichment of 0.5 to 6.2‰. Later designs used 8 mm of oil, which resulted in ^{18}O enrichment of less than 0.6‰ over a six-month period.

Beekman and Sunguro (2002) installed triplicate sets of CRCs, farmers' rain-gauges and metal rain collectors. They found that the CRCs gave slightly elevated levels of chloride