A preliminary investigation of the oxygen and hydrogen isotope hydrology of the greater Cape Town area and an assessment of the potential for using stable isotopes as tracers

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Abstract

The oxygen and hydrogen isotope composition of rain-water, groundwater and mains supply water was determined with the aim of assessing the potential for applying these isotope systems to problems of urban hydrology in the greater Cape Town area. Water treatment plants supplying mains water to Cape Town produce water with a seasonal variation in hydrogen (H) and oxygen (O) isotope composition. In September 1996, at the end of the wet winter months, the treated water had δD and $\delta^{18}O$ values that were 12 and 2‰ higher, respectively, than the values of April 1996 at the end of the previous summer. The δD and $\delta^{18}O$ values of natural springs on the slopes of Table Mountain show a good correlation, with a line of best fit that is parallel to that of the global meteoric water line, but enriched in deuterium. Groundwater from the shallow Culemborg-Black River aquifer and the extensive Cape Flats aquifer have δD and $\delta^{18}O$ values which plot closer to the global meteoric water line. These relatively minor differences in isotope composition between the springs and groundwater appear to be due to differences in the isotope composition of ambient rain-water.

The observed differences in δD and $\delta^{18}O$ values between mains water and groundwater in the greater Cape Town area are not significant in winter, but towards the end of summer are of the order of 10 and 1.6‰, respectively. We suggest that O- and H-isotope data would effectively discriminate between mains water and groundwater for most of the greater Cape Town area in the summer and autumn months.

Introduction

Hydrogen and oxygen isotope studies have potentially important applications to urban hydrology. Where differences in isotope ratios exist between potential sources in an urban region (e.g. groundwater, piped mains water, rain-water, swimming-pool water) stable isotope ratios can be used to monitor the origin of water. Hydrogen and oxygen isotope ratios are highly conservative tracers for monitoring the origins of water. Because oxygen and hydrogen are the major constituents of water, it is practically impossible for their isotope ratios in water to change, except where there is substantial amounts of evaporation and/or mixing with significant proportions of water of different isotope ratio. In South Africa, Verhagen and Butler (1995) used O- and H-isotopes along with other environmental tracers to study groundwater in an urban/industrial area at Midrand, near Johannesburg. They found that leakages and waste water derived from the Rand Water mains system could be traced, as its isotope composition differed from most naturally recharged groundwaters. Some private boreholes in the Pretoria (Butler and Verhagen, 1997) area contain a significant component of mains water (up to 100%). There is also the possibility that pollution by sewage in groundwater could be traced using O- and H-isotopes because sewage might be expected to have isotope ratios similar to mains water. Water is not an abundant resource in South Africa, and for this reason alone, water supplies need to be effectively managed. In recent years, Cape Town has experienced a large increase in population, mainly in informal settlements. There will be increasing pressure on water supplies in the years to come.

The aim of this paper is to evaluate the potential of O- and H-isotopes as hydrological tracers of the origin of groundwater in the Cape Town area. As we shall show, seasonality plays an important role in maximising potential differences between the different water reservoirs.

Geographical and geological outline

Geology of the Cape Town area

The oldest geological formations in the vicinity of Cape Town (Fig. 1) belong to the Malmesbury Group (Theron et al., 1992; Hartnady and Rogers, 1990). The Peninsula Granite batholith intruded these rocks at about 550 Ma (Burger and Coertze, 1973) and the approximately vertical contact between the Malmesbury Group and the granite lies just to the SW of the city centre (Fig. 2). The Cape Granite and the Malmesbury Group metasedimentary rocks are unconformably overlain by the quartzites of the Table Mountain Group. The almost horizontal sandstones of the Peninsula Formation have been linked to the same formation capping the mountains on the eastern fringe of the Cape Flats (Fig. 1.). Post-Palaeozoic erosion has removed the Table Mountain Group between False Bay and Table Bay to create the Cape Flats (Fig. 1) an area of low topography separating the Peninsula from the inland hills.

Sediments of the Cenozoic Sandveld Group overlie bedrock of much of the Cape Flats. Of special interest for this study is the Springfontyn Formation, which is a chiefly aeolian formation of fine to medium quartzose sand, and is exposed over most of the central part of the Cape Flats. It forms the dominant part of

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