



# An investigative comparison of purging and non-purging groundwater sampling methods in Karoo aquifer monitoring wells



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## ABSTRACT

An investigation was conducted to statistically compare the influence of non-purging and purging groundwater sampling methods on analysed inorganic chemistry parameters and calculated saturation indices. Groundwater samples were collected from 15 monitoring wells drilled in Karoo aquifers before and after purging for the comparative study. For the non-purging method, samples were collected from groundwater flow zones located in the wells using electrical conductivity (EC) profiling. The two data sets of non-purged and purged groundwater samples were analysed for inorganic chemistry parameters at the Institute of Groundwater Studies (IGS) laboratory of the Free University in South Africa. Saturation indices for mineral phases that were found in the data base of PHREEQC hydrogeochemical model were calculated for each data set. Four one-way ANOVA tests were conducted using Microsoft excel 2007 to investigate if there is any statistically significant difference between: (1) all inorganic chemistry parameters measured in the non-purged and purged groundwater samples per each specific well, (2) all mineral saturation indices calculated for the non-purged and purged groundwater samples per each specific well, (3) individual inorganic chemistry parameters measured in the non-purged and purged groundwater samples across all wells and (4) Individual mineral saturation indices calculated for non-purged and purged groundwater samples across all wells. For all the ANOVA tests conducted, the calculated alpha values ( $p$ ) are greater than 0.05 (significance level) and test statistic ( $F$ ) is less than the critical value ( $F_{crit}$ ) ( $F < F_{crit}$ ). The results imply that there was no statistically significant difference between the two data sets. With a 95% confidence, it was therefore concluded that the variance between groups was rather due to random chance and not to the influence of the sampling methods (tested factor). It is therefore possible that in some hydrogeologic conditions, non-purged groundwater samples might be just as representative as the purged ones. The findings of this study can provide an important platform for future evidence oriented research investigations to establish the necessity of purging prior to groundwater sampling in different aquifer systems.

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## 1. Introduction

It is important to collect groundwater samples which are representative of aquifer hydrogeochemical conditions. Groundwater samples can be collected using either purging or non-purging methods. Purging involves the removal of stagnant water from the well prior to sampling to allow replenishment with water from the aquifer. During low flow purging it is recommended that parameters such as temperature or electrical conductivity (EC) be continuously measured until they become stable before samples can be collected (U.S. Geological Survey, 1980). Other studies such

as Unwin (1982) recommends the removal of 3 or more bore volumes to replenish the well before a sample can be collected. Detailed guidelines on well purging procedures and techniques are discussed in a number of studies which includes; Barcelona et al. (1984, 1985), Barcelona and Helfrich (1986) and Puls and Barcelona (1996).

However on the contrary, other studies have also suggested that that depending on well construction configuration, samples collected without purging can still be representative of aquifer hydrogeochemical conditions. Field observations of horizontal laminar flow under natural conditions by Kearn et al. (1992) showed that stagnant water in the well casing does not mix with water in the well screen. This observation implies that groundwater samples collected from the well screened interval should be representative of water from the aquifer since it is continuously

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replenished by horizontal laminar flow across the well screen. Robin and Gilham (1987) also showed the existence of representative water within a well's screened interval due to continuous renewal by groundwater flow, thereby presenting the possibility of collecting representative groundwater samples without purging. To facilitate continuous replenishment of water in the screened interval, the monitoring well has to be screened along groundwater flow zones. Groundwater flow zones can be identified during drilling through the analysis of hydrogeologic features such as; water strikes and lithology. If data on water strikes is not available, borehole profiling techniques can be used to identify main groundwater flow zones which can be screened and targeted for non-purging sample collection.

Groundwater sampling is conducted for different purposes and this determines the chemical parameters for laboratory analysis. The context of this study is confined to groundwater sampling from wells installed to monitor potential contamination migration at regulated facilities such as mines, landfills and other wastes sites.

In South Africa, monitoring of inorganic chemistry in groundwater is a requirement on mines (DWAF, 2007) and waste management facilities (DWAF, 1998). Available South African guidelines for groundwater sampling that were developed by Weaver et al. (2007) encourages purging prior to groundwater sampling whenever possible. However these guidelines are not accompanied by field based evidence to justify the need for purging whenever possible. The applicability of purging method is even more questionable in aquifers where wells can dry out during purging such that continuous monitoring of parameters until they have stabilized becomes impossible. In such hydrogeological conditions, the recommended approach is to purge until dry and collect the sample after the well has recovered (US EPA, 2004; Weaver et al., 2007). Groundwater sampled from a well that has recovered is presumed to reflect aquifer hydrogeochemical conditions since the water would have come directly from the aquifer. However this cannot be equated to collecting the sample after stabilization of continuously monitored field parameters during purging in wells that do not run dry.

This study was designed to investigate if there is any statistically significant difference between non-purged and purged groundwater inorganic chemistry parameters and mineral saturation indices. Four one-way ANOVA tests to statistically compare the inorganic chemistry parameters and mineral saturation indices between non-purged and purged groundwater samples were conducted using Microsoft excel 2007. Saturation indices of the mineral phases that were found in the data base of PHREEQC (Parkhurst and Appelo, 2013) for windows hydrogeochemical model were calculated for this investigation.

## 2. Methods and materials

### 2.1. Theoretical background – monitoring wells

A total of 15 existing monitoring wells were used for this investigation. Wells are located at different sites within the Karoo Basin aquifers of South Africa. It is important to highlight that the emphasis on this article is not on investigating hydrogeochemical characteristics in these aquifers but rather comparison of non-purging and purging groundwater sampling methods. Detailed geological and hydrogeological characteristics of typical Karoo aquifers are therefore beyond the scope of this study.

This comparative study presumes that in order to obtain non-purged representative samples, these samples have to be collected from the groundwater flow zones. In order to delineate the groundwater flow zones, the well has to be profiled. For this study, wells

were profiled using EC meter as it was the only tool available. However because of the site specific nature of groundwater occurrence and flow characteristics it is impossible to describe and show the lithology, construction configurations and EC profiles for each well used in this article. A conceptual illustration of EC profiles associated with groundwater flow zones in typical weathered and fractured-rock Karoo aquifers is presented in Fig. 1b.

Firstly is the weathered aquifer that overlies fresh bedrock. In such a hydrogeological setting, the contact area/plane between the weathered and underlying fresh rock becomes a preferential groundwater flow path as illustrated in Fig. 1a. This occurs because the fresh underlying bedrock has low permeability thus will retard vertical downward groundwater flow and as a result most of the groundwater conceptually flows along the contact plane. Profiling of EC in wells drilled in such a geological formation would conceptually show an anomaly at the contact plane thus indicating the location of a groundwater flow zone. Sometimes more than one groundwater flow zone exists and in other instances it might be necessary to collect samples from different flow zones. Conceptually, the nature of the EC anomalies will depend on the hydrogeochemical characteristics of the flowing groundwater (Fig. 1b). When the flowing groundwater is hydrogeochemically contaminated or polluted, elevated concentrations of ionic species would result in rising EC anomaly at the flow zone. If the flowing groundwater is fresh, a decreasing EC anomaly is expected due to low ionic concentrations. Other parameters that can be profiled include; pH, dissolved oxygen (DO), oxidation reduction potential (ORP) and temperature.

Bedding plane fractures at contact areas of different sedimentary layer formations are also a common feature in Karoo aquifers (Botha et al., 1998). In such aquifers, bedding plane fractures constitute the main groundwater flow zones and are respectively associated with profile anomalies.

### 2.2. Groundwater sampling

Two sets of groundwater samples were collected from each of the 15 monitoring wells. The first set of samples was collected from the main groundwater flow zone using a depth specific bailer prior to purging. Prior to non-purging sampling, wells were profiled using EC probes to identify groundwater flow zones. After collection of the non-purged samples, wells were then purged at a rate of 0.1 L/min using low flow pump until they were dry. Wells were then left to fully recover before samples were collected. Prior to all sample collection, bottles were rinsed with hydrochloric acid at a pH of 2 to remove leachable material. Samples were collected into 500 ml polyethylene bottles. Collected groundwater was also filtered using 0.45 µm Millipore membranes. After sampling, the bottles were tightly closed to protect from exchange with atmospheric gases, labeled, stored (<4 °C) and delivered to the analytical laboratory within 24 h. Electrical conductivity and pH for each collected groundwater sample were measured in the field using respective digital meters.

### 2.3. Inorganic chemistry analysis

Groundwater samples were analysed for heavy metals, major and minor ions. The analysis was conducted at the Institute of Groundwater Studies (IGS) laboratory of the University of the Free State in South Africa. Analysis for cations and heavy metals was done using a PerkinElmer Optima 3000 DV Inductively Coupled Plasma (ICP) and the Dionex DX-120 Ion Chromatograph (IC) was used for the anions. Alkalinity measurements were made using a TW alpha plus titration kit. All the analyses were conducted based on the guidelines provided in the Standard Methods for the Examination of Water and Wastewater (American Public Health

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