Infrastructure as a driver for economic growth and integration in African: what is the way forward?
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TECHNOLOGIES FOR GROUNDWATER QUALITY MONITORING IN RURAL AREAS

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Access to clean and portable water is a great challenge to most rural communities of South Africa's Mpumalanga province. Studies have revealed that groundwater, the main source of drinking water was not fit for human consumption in some rural areas in Mpumalanga province due to high concentration of certain elements. The water from groundwater sources is distributed directly to communities without any purification or regular water quality monitoring. Some rural areas have mostly relied on groundwater for domestic and agricultural use due to the recent reports of water shortages in South Africa. A scalable and flexible model developed as part of this research will respond quickly to change and will assist with the monitoring of the quality of the groundwater from the boreholes. In this research we proposed technologies that could be used to build a model to analyse the physical and chemical constituents that highly contaminate groundwater, the main source of drinking water in Mpumalanga province. The quantitative research method was used to determine the chemical constituents that highly contaminated groundwater supplied by the boreholes in the rural communities of Mpumalanga province.

*Keywords***:** water quality, determining chemical constituents of groundwater

1 INTRODUCTION

The quality of drinking water is the most powerful determinant of health, Therefore an assurance of drinking water safety is the foundation for the prevention and control of waterborne diseases. The 2015 updates on the Millennium Development Goals (MDGs) assessment a continuous campaign of the World Health Organization and UNICEF progress on sanitation and drinking water indicated that the global target for drinking water was met in 2010 and 91 percent of the global population now uses an improved drinking water source (WHO and UNICEF, 2015). The report shows that 2.6 billion people have gained access to an improved drinking water sources since 1990 and 96 percent of the global urban population uses improved drinking water sources compared with 84 percent of the rural population. The report also indicated that eight out of ten people, still without improved drinking water sources, live in the rural areas. In the year 2015, it has been reported that 663 million people still lack improved drinking water.

In our paper we propose technologies that can be used to monitor groundwater quality in the rural area of South Africa. Mpumalanga province, that lies in the eastern region of South Africa has been selected as the study area for this paper due to the recent reports about the water shortages and also due to the fact that most rural communities there rely on groundwater for domestic use. For the majority of the rural communities in the province, there is a shortage of quality water supply and the people, who do not have tap water, rely on groundwater (boreholes) for domestic use and other daily activities.

Various studies (Mpenyana-Monyatsi et. al, 2012) suggest groundwater the main source of drinking water is not fit for human consumption in some rural areas. The high concentration of Magnesium, Calcium, Fluoride, nitrates, levels of turbidity and poor quality of water source poses a serious threat to the health of consumers. It has been predicted (Postel, 2003; Barker, 1997; Department of Water Affairs, 2001) that by 2015, half the world's population could be facing serious water shortages and people could also run out of safe drinking water due to the unpredicted rise in the population and the assessment degradation of water sources. In 2007 (Water Research Commission, 2007) the South Africa Water Research Commission conducted a study of water loss/wastage in 62 municipalities in South Africa.

The loss amounted to approximately 36% of the total amount of water supplied by the municipalities. Was the loss of non-revenue water, i.e. Unbilled both physical and commercial losses within the reticulation system (The water wheel, 2007). Recently it has been reported that drought currently affects 173 of 1628 water supply schemes nationally, serving approximately 2.7 million households and the scale of the effect of the drought and the state of water security in the country "an estimated 6500 standalone rural communities are currently experiencing water shortages" (Department of Water and Sanitation, 2015), these are mostly situated on the KwaZulu-Natal, Mpumalanga, Limpopo and the North West province.

As the dry periods extend and local water resources get depleted, rivers and taps get dry, this will force most rural communities to depend on groundwater Wells as their source of water for domestic and other activities. The increase in a number of boreholes in the province will result in a need for a centralised solution that will assist to analyse and monitor the physical and the chemical groundwater quality and increases the awareness of problems and issues at the water sources assisting boreholes operators and policy makers to make rational and equitable decision with respect to water resource management. Domestic water refers to water which is used in the domestic environment and refers to all uses water can be put into in the environment (Department of water affairs and forestry, 1996) which includes water for:

- Drinking
- Food and beverages preparation
- Hot water system
- Bathing and personal hygiene
- Washing, for example, dishes
- Laundry
- Gardening, which may include water ponds

In South Africa, biomonitoring technique is used for the collection of water samples data at different water sources and the analysis of the samples at the laboratory, this includes quality of surface water and groundwater. The samples collected are analysed at the laboratories of the Institute for water quality studies and the data is stored on the Department of Water Affairs and Forestry Water Management System (WMS) database.

This paper proposes a groundwater monitoring model using cloud computing to check the water quality and the Cloud is used to store, manage and process data. It allows any web-enabled devices to view the results.

The main objective of the paper is to determine technologies that can be utilized to to monitor the quality of groundwater in the rural areas South Africa. The sub-objectives are:

- To determine the quality, physical and chemical composition that ensures groundwater is good for domestic use in South Africa's Mpumalanga province.
- To determine technology that can be used to effectively to analyse and monitor the quality of groundwater in the rural areas.

2 SIMILAR WORK

Some of the technologies used to improve the water monitoring quality are as follows. In Bangladesh (Kamal et. al, 2000) a study used a GIS (Global Information System) to develop a model for monitoring groundwater's Arsenic contamination, where areas with water contamination could be displayed on the GIS application to help policy makers decide proper groundwater utilization and thereby taking necessary steps to supplying safe drinking water to the domestic and industrial areas.

Sensor technology together with the Microcontroller (Jain, 2014) was used to design a Microcontroller based system for water quality monitoring. The department of Civil Engineering at the University of Cape Town conducted a study (Rivett et. al, 2013) that investigated the use of cellphone application to assist with data collection at the groundwater sources and the data collected was then processed via GPRS network to a centralized server and stored in a database.

3 RESEARCH METHODOLOGY

Mpumalanga province, that lies in the eastern South Africa has been selected as the study area for this paper due to the recent reports about the water shortages and also due to the fact that most rural communities rely on groundwater for domestic use. In this section we discuss the methods used to monitor ground water quality. This section provides information on technologies that can be utilized to improve the current methods.

In our model, secondary groundwater data requested from the Department of Water Affairs and Forestry Water Management System (WMS) database for the target area Mpumalanga province was stored in MYSQL database and the application to present the data to the user was hosted in the same server where MYSQL database was installed. The application server was then exposed to the Internet through a firewall to ensure the three basic security concepts important to information on the Cloud which are confidentiality, integrity and availability are imposed to the solution.

The developed model shows the location of the borehole in the province using GIS technology, coordinates (Longitude and Latitude) and also the Map view, status of rural water supply and also the effects the water might have on health.

One can also configure alerts SMS or Email to be sent to a group of users if the health effects are detected for a certain groundwater sources. The system diagram is shown in figure 1.

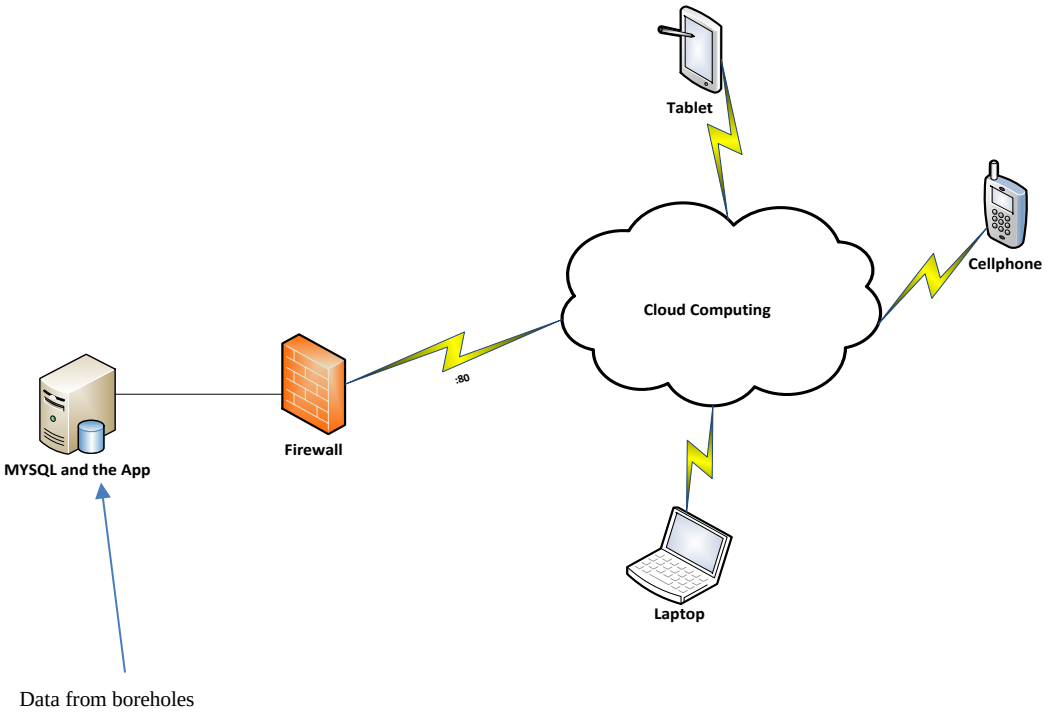

Figure 1. Cloud computing model for ground water quality monitoring

4 DATA ANALYSIS AND RESULTS

This section provides information on the data analysis and results conducted using the proposed model. Table 1 shows the physical and chemical qualities that were analysed using the proposed model that are applicable to determine whether the quality of groundwater is fit for domestic use according to the South Africa water quality guidelines for domestic water use.

The list is by no means comprehensive and site-specific conditions may necessitate a more comprehensive list of substances to be analysed.

Table 1. Water quality substances of key relevance to the domestic use (DWAF, DoH &WRC, 2000)

KEY SUBSTANCES	RELEVANCE TO THE DOMESTIC USER
Physical quality	
Electrical conductivity Total dissolved salts	Serves as a general indicator of change in water salt quality and affects the taste and "freshness" of the water
pH 6.5 -8.5	Affects the taste and corrosivity of the water
Turbidity	Indicates the cloudiness of the water, and affects the risk of infectious disease transmission
Chemical quality	
Arsenic	Excessive amounts can make the water poisonous and may also cause cancer
Cadmium	May affect the toxicity of the water
Calcium	Causes scaling in pipes; affects taste of water
Sodium and chloride	May impart a salty taste to the water
Fluoride	Excessive amounts stain teeth and cause crippling skeletal deformities
Iron and manganese	May discolour water; excessive amounts may be toxic
Total hardness	Affects the scaling and foaming quality of the water
Magnesium	Excessive amounts make water bitter and may cause diarrhoea
Nitrate and nitrite	May be toxic to infants
Potassium	Imparts a bitter taste; toxic in large amounts
Zinc	May affect the taste of water - makes the water bitter

Secondary data was used to determine the physical and chemical quality of the groundwater in Mpumalanga province. The sample selected and analysed, indicated that the groundwater used for domestic in the rural areas of Mpumalanga province, the results showed that the groundwater samples collected from boreholes in local municipalities were within the recommended limit for no risk in terms of pH, temperature and TDS. The pH mean average values ranged from (6.5 to 9.5) and temperature (1-25^{o} C).The threshold for dissolved salts in water is in the region of 45 mS/m (300 mg/R TDS), hence a slightly salty taste may be detected, no effect on plumbing and appliances. In most of the municipalities, it was found that the groundwater has a noticeable salty and bitter taste, but is well tolerated no health effects are likely. The borehole located at Mbombela Local Municipality, it was found that the water tastes extremely salty and bitter.

Effects such as corrosion and scaling increase short-term consumption leads to disturbance of the body's salt balance. At high concentrations, noticeable short-term health effects can be expected. At the Albert Lutuli local Municipality due to high values on electrical conductivity measurement, the model showed that the health effects may lead to crippling skeletal fluorosis are likely to appear on long-term exposure. The model

has the capability based on the measurement of the physical and chemical constituents; it can predict the health effect that can be experience in adult, children and infants over a long-term and also the short-term as it can be seen above. Figure 2 shows the analysis of groundwater the physical and chemical qualities based on the samples selected.

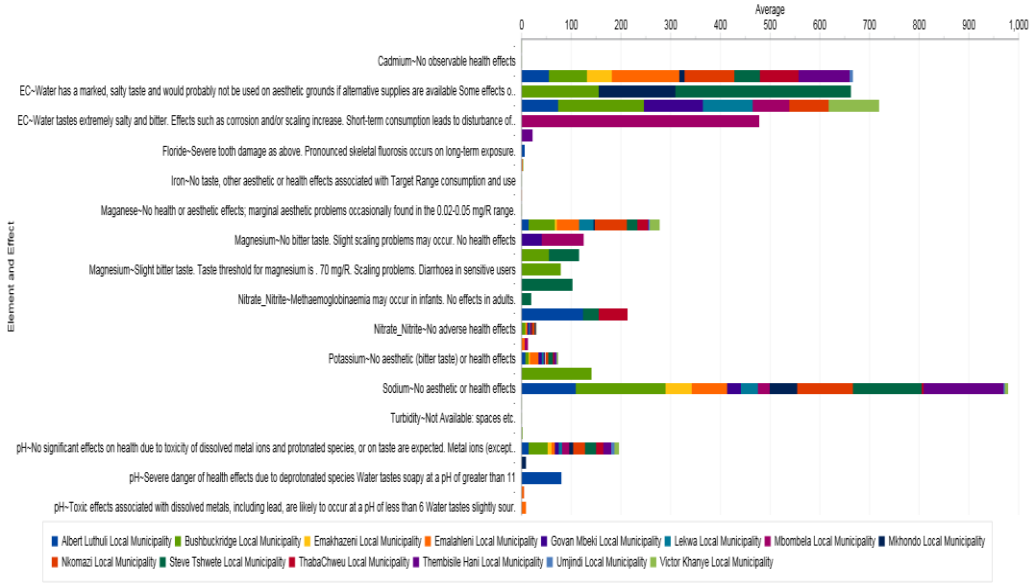

Figure 2. Groundwater Physical and Chemical quality analysis

5 CONCLUSION

In most rural communities in the Mpumalanga province, there is a shortage of quality water supply. The people, who do not have tap water there, rely on groundwater (boreholes) for domestic use and other daily activities due to water shortage. In this paper we developed a cloud based model for monitoring ground water quality in rural areas. This model is an excellent tool to assist water researchers in deciding proper groundwater utilization and taking necessary steps to supplying safe drinking water to the domestic and industrial areas. We determined elements and their effects for various municipalities using technologies.

We were able to detect physical and chemical constituents on groundwater boreholes that may have an effect on health and other factors of interest could be analysed using the technologies for the prevention measures to be put in place. The reporting mechanisms in rural areas to determine water quality standards in borehole water supply will increase and also the awareness related to problems and issues at the water supply site, at borehole operator level indicating the status of rural water supply and the requirements of management and the need for data collection for national monitoring purpose.

The future research work aims at the technologies to be used to source primary groundwater data from the boreholes and a comprehensive study of the physical and

certain chemical composition of water in the rural areas that is harmful to humans. There is more scope for testing of a water quality monitoring system with different test samples and more provinces and study the obtained results for real-time monitoring of ground water quality and to determine ways to improve the quality simultaneously.

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