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Characterisation of Local Borehole Water within the Platinum Belt in Mokopane, Limpopo, Republic of South Africa

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Abstract
South Africa is known to be a water scarce country, with an average rainfall of about 495 mm per annum. Around 40% of the world's population is affected by freshwater scarcity because of growing urbanization, industrialization, and excessive use of natural resources. With no adequate water infrastructures in place, rural areas in Mokopane Town rely on borehole water for everyday endeavours. The impact of Mining has subsequently led to the degradation of the water quality in the areas in which mines operate. Water pollution is one of the global concerns with the goal of improving water quality and reducing the negative effects on human and ecological health. The increase in mining activities over the Mogalakwena catchment possess a water quality risk due to mine water decant and fluorides caused by the geology of the area. By characterising the water samples in the area, the Physio-chemical analysis of the study showed most physical properties of the groundwater to be within the acceptable WHO standards. Chemical properties showed very high Mg values (As high as 139 mg/L) and Fluoride values as high as 2.05mg/L. Nitrate and Nitrite showed poor and unacceptable(>10mg/L) values on 69% of the water samples. This characterisation used techniques such as environmental assessment, Inductive coupled plasma optical emission spectrometry (ICP-OES), conductivity probe, water turbidity, total suspended solids method, ultraviolet visible spectroscopy, and pH. The results were analysed using GIS to map out the boreholes and their respective water results. It's recommended that Mogalakwena Municipality needs to monitor public boreholes in the area and upload results on ground water assessment for easier access on information, for the people to know the condition of the water they receive.

Keywords: Groundwater, Water Quality, GIS Mapping

1.Introduction
Republic of South Africa is considered a water scarce country with an average rainfall of about 495mm per annum [1]. Water is a vital necessity for human survival, and its environmental significance is progressively growing because of its limited availability and ongoing contamination. Water pollution is one of the global concerns that civilization must solve in the twenty-first century, with the goal of improving water quality and reducing the negative effects on human and ecological health [2]. Around 40% of the world's population is affected by freshwater scarcity because of growing urbanization, industrialization, and excessive use of natural resources [3].

Heavy metals are inevitably found in the earth's crust. Mining, industrial production and water purification usually generate heavy metals and metallic substance that all contribute to environmental pollution and human exposure to heavy metals [3]. For this reason, heavy metal ions are among the most emitted pollutants, and they are chiefly concerning. Copper (Cu), cadmium (Cd), zinc (Zn), lead (Pb), mercury (Hg), arsenic (As), silver (Ag), chromium (Cr), iron (Fe), and platinum (Pt) group elements are heavy metals and metalloids with an atomic density more than 4 g/cm3. These toxic metals are discharged into the water daily from a variety of natural and artificial sources. The typical quantities of Cr, Mn, Fe, Co, Ni, As, and Cd detected in surface water bodies in numerous locations across the world are substantially over the maximum permissible values for drinking water.

2. Literature review of Mining activities over the Mokopane-Mogalakwena catchment

Limpopo is known to be one of the poorest provinces in South Africa hence most infrastructure for development is either ignored or not a matter of urgency. It has also been observed that most of the Limpopo basin is situated in Limpopo province, the province still has no adequate water supply to its residences [4].

Apart from climate change and pollutions due to human activities, mining poses as a risk far greater. Limpopo is considered as a platinum belt which in turn implies the disadvantages. Most mines rely on groundwater for activities and productions for mining. Majority of the villages uses pit toilets as there are no adequate services in the areas which increases the chances of groundwater pollution, Mogalakwena is rich in minerals such as platinum, iron ore and chromite which makes it of economic importance to both South Africa and Africa [5].

Regarding drinking Water and mine effluent standards in south Africa, the SANS 241:2015 (Table 1) articulates the limits and associated risks for domestic water [6]. The SANS 241:2015 details: 1) Health risks: parameters falling outside these limits may cause acute or chronic health problems in individuals, 2) Aesthetic risks: parameters falling outside these limits indicate that water is visually, aromatically, or palatably unacceptable, 3) Operational risks: parameters falling outside these limits may indicate that operational procedures to ensure water quality standards are met may have failed.

Table 1: Drinking Water and mine effluent standards within the SANS 241:2015. (Source: SANS 241:2015)

MICROBIOLOGICAL DETERMINANDS		
	Risk	**Limits**
E.coli **or Fecal coliforms count/100ml**	health	**Not detected**
Cytosporidium species count/10mL	health	**Not detected**
Giardia species count/10mL	health	**Not detected**
Total coliforms count/100ml.	operational	**< 10**
Heterotrophic plate count count/1ml	operational	**< 1000**
PHYSICAL, AESTHETIC, OPERATIONAL AND CHEMICAL DETERMINANDS		
Free chlorine mg/L	health	**≤ 5**
Monochloramine mg/L	health	**≤ 3**
Colour Pt-Co	aesthetic	**< 15**
Conductivity at 25degC mS/m	aesthetic	**≤ 170**
Total dissolved solids mg/L	aesthetic	**≤ 1200**
Turbidity	operational	**≤ 1**
	aesthetic	**≤ 5**
pH at 25degC	operational	**≥ 5 and ≤ 9.7**
Nitrate as N mg/L	health	**≤ 11**
Nitrite as N mg/L	health	**≤ 0.9**
Nitrate-Nitrite ratio		**≤ 1**
Sulfate as $SO4^-$ mg/L	health	**≤ 500**

	aesthetic	**≤ 250**
Fluoride as F^- mg/L	health	**≤ 1.5**
Ammonia as N mg/L	aesthetic	**≤ 1.5**
Chloride as Cl^- mg/L	aesthetic	**≤ 300**
Sodium mg/L	aesthetic	**≤ 200**
Zinc mg/L	aesthetic	**≤ 5**
Antimony □g/L	health	**≤ 20**
Arsenic □g/L	health	**≤ 10**
Barium □g/L	health	**≤ 700**
Boron □g/L	health	**≤ 2400**
Cadmium □g/L	health	**≤ 3**
Chromium □g/L	health	**≤ 50**
Cobalt □g/L	health	**≤ 500**
Copper □g/L	health	**≤ 2000**
Cyanide □g/L	health	**≤ 200**
Iron □g/L	health	**≤ 2000**
	aesthetic	**≤ 300**
Lead □g/L	health	**≤ 10**
Manganese □g/L	health	**≤ 400**
	aesthetic	**≤ 100**
Mercury □g/L	health	**≤ 6**
Nickel □g/L	health	**≤ 70**
Selenium □g/L	health	**≤ 40**
Uranium □g/L	health	**≤ 30**
Vanadium □g/L	health	**≤ 200**
Aluminium □g/L	operational	**≤ 300**
Total organic carbon mg/L	health	**≤ 10**
Chloroform □g/L	health	**≤ 300**
Bromoform □g/L	health	**≤ 100**
Dibromochloromethane □g/L	health	**≤ 100**
Bromodichloromethane □g/L	health	**≤ 60**
Trihalomethane ratio		**≤ 1**
Microcystin □g/L	health	**≤ 1**

Phenols □g/L	aesthetic	≤ 10

3. Study area

All samples were collected in the town of Mokopane, which is one of the most Northern-west village situated at 24°11′2″S 29°0′46″E toward Botswana border post Glober's bridge along N11 in the municipality of Mogalakwena, district Waterberg, Limpopo Province, South Africa, according to the method described by [7]. Whereby the laboratories participating in this study were strategically selected to provide reasonable geographical representation in the town of Mokopane. Mokopane is considered as a hot semi-arid area, with an average rainfall of 495mm per annum [8]. Temperatures range between from an average of 23.4 °C in summer to an average of 13.0°C during the cold winter seasons as per table below. Most of the Precipitation is in January with an average of 94mm while the lowest precipitation of 1mm is in June, see table 2 (en.climate-data.org) [9].

Table 2: Average Temperatures 1991- 2021. (Source: Climate-data.org).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Min. Temperature °C	17	17	15.8	13	10.2	7.7	6.9	9
Max. Temperature °C	27.7	28	26.9	24.4	22.7	20.3	20.1	23.8
Avg. Temperature °C	22.3	22.4	21.2	18.5	16.1	13.6	13.1	16.1
Precipitation/ Rainfall mm	115	74	65	35	10	4	3	3
Humidity (%)	63	61	61	61	51	49	45	39
Rainy days(d)	9	7	6	4	1	1	0	1

Geologically, the study site is part of the northern lobe of the Bushveld complex containing the Platreef, which is one of the world's largest deposits of platinum-group element (PGE) mineralization, as well as major nickel and copper sulfites. The study area's topography consists of low laying mountains and high slopes with sedimentary rocks. The Platreef is only a small part of the Rustenburg Layered Suite's ultramafic-mafic rock suite [10].

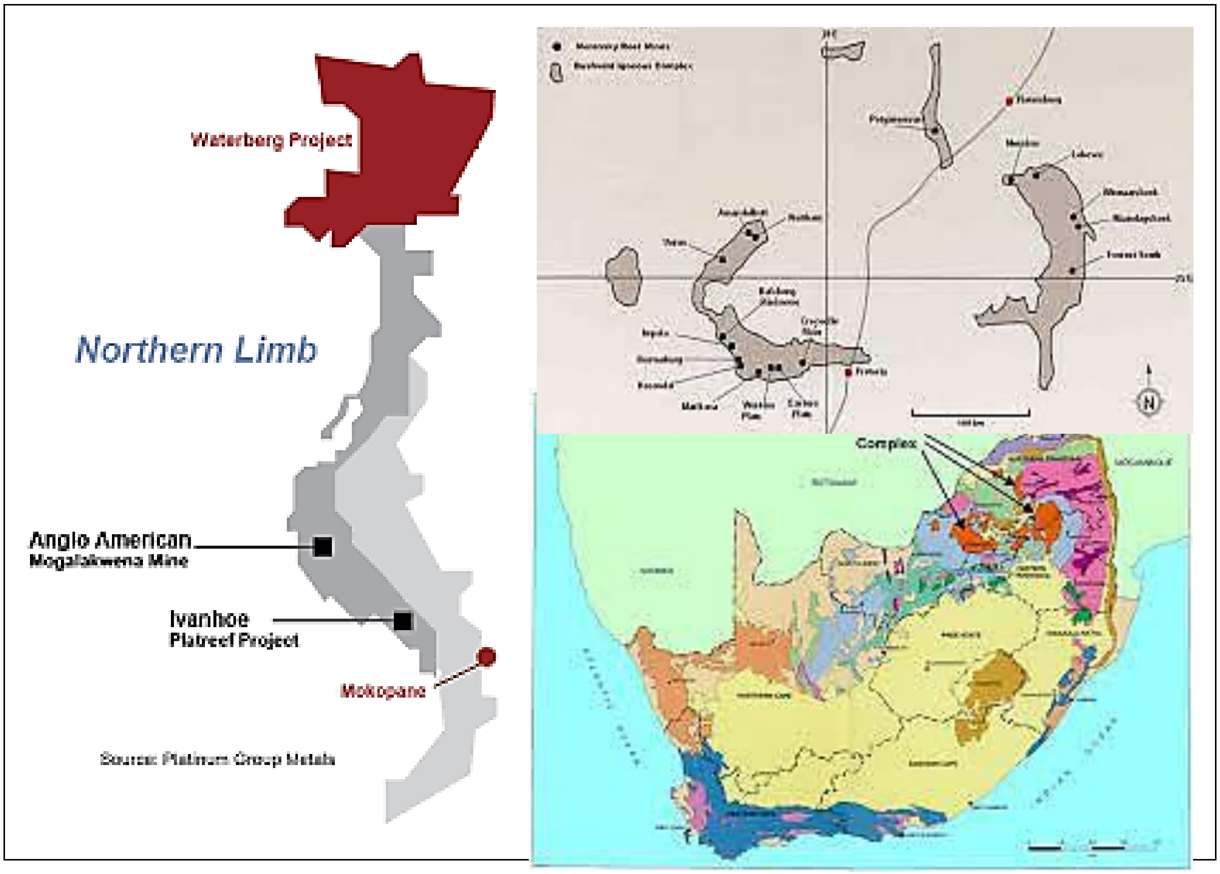

Figure 1. Location of the study area. (Source: Author).

4. Methodology/Water sample collection

Water samples were collected based on historical information indicating sites which are easily accessible from 63 community boreholes along the Bushveld Ingenious Complex (BIC) in the northern limb. Samples were collected in September during summer in 50ml presterilized bottles. The water was left to run for 3-4 minutes before collection. The physical parameters were measured directly after sampling and recorded. Collection of samples were done as per the guidelines in SANS 241 for water sample collection. Samples were then taken to the lab for analysis and compared against accepted water quality standards.

5.Results and discussions

Water sample results were recorded and compared to WHO water quality standards to establish if the water was portable and fit for human consumption.

5.1 Physical analysis

5.1.1 Temperature

Samples were collected and temperature measured on site using water quality tester. The results are recorded below. Temperature influences the living and non-living components of the environment thus making it the most important physical parameter. The samples were collected during the beginning of summer with the area’s mean value being 32 °C as in Table 1 below. Sample Temperatures were between 23°C and a maximum of 27°C. There is no temperature set limits for drinking water set by WHO.

5.1.2 pH

The pH value is a crucial parameter to consider when characterizing water, as it is one of the variables that regulate heavy metal ion absorption. Henceforth, the determination of the optimum pH to see its impact on the retention of heavy metals such as Cu, Pb, and Cd. The pH value will advise which level is optimum for the quantitative extraction of metal ions and metal recovery, which is about 99% [11].

The pH results spanning over the entire study area was found to be suitable for drinking purposes and classified as quality with majority of the samples being of good quality standard and a few samples being acceptable per the WHO quality standard.

Table 3: pH

SI Units	WHO Standard	Quality Standard			
		Good	Acceptable	Poor	Unacceptable
pH scale	6,5 - 8,5	6,5-8,5	5,5- 6,5 and 8,6-10	4,5-5,4 and 10,1-11,5	<4,5 and >11,5

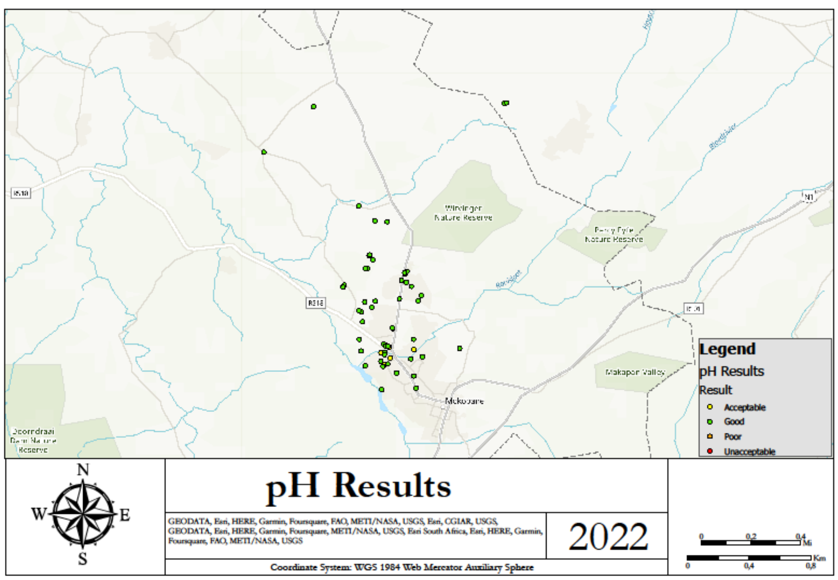

Figure 2: Map showing boreholes with varying pH results (Source: Researchers).

5.1.2 Electrical Conductivity (EC)

Electrical Conductivity was found to be of good standard as per the WHO will all samples being of ideal value with a minimum of 77 uS/cm to 222 uS/cm.

Table 4: Electrical Conductivity.

SI Units	WHO Standard	Quality Standard			
		Good	Acceptable	Poor	Unacceptable
uS/cm	<600	<300	300-600	601-600	>600

5.1.3 Total Suspended Solids (TDS).

The Total suspended solid water quality results were found to be alarming and of unacceptable quality standard as most samples were between poor and unacceptable values with results as high as 1648 mg/L making the water quality to be unfit for human consumption as per the WHO Standard.

Table 5: TDS.

SI Units	WHO Standard	Quality Standard			
		Good	Acceptable	Poor	Unacceptable
mg/L	<600	<300	300-600	601-1200	>1200

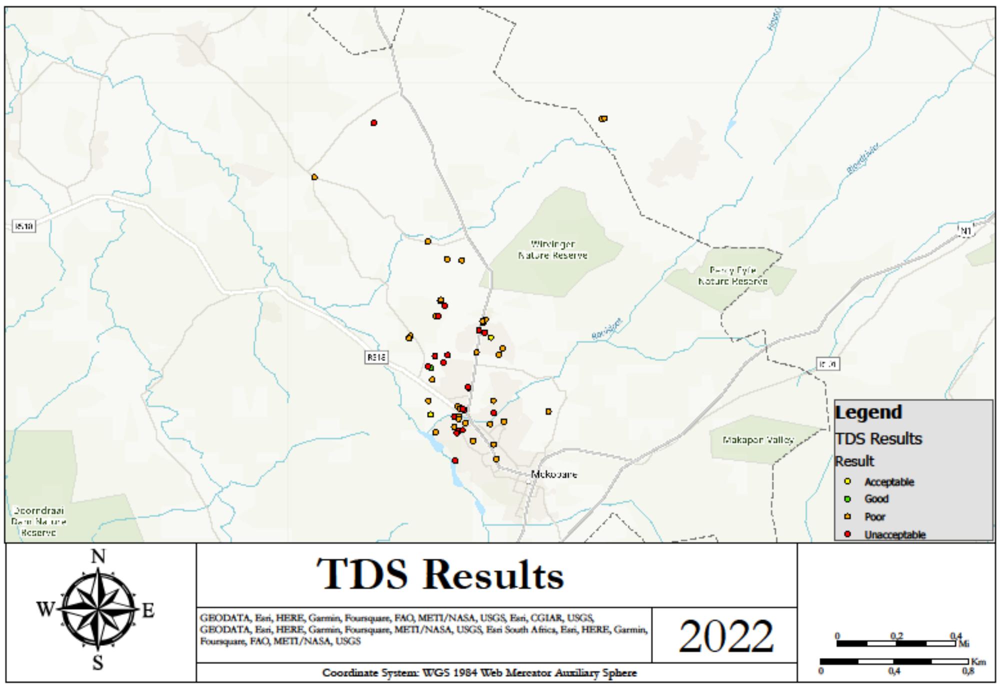

Figure 3: Map showing boreholes with varying TDS results (Source: Researchers).

5.2 Chemical parameters: Anions.

5.2.1 Chloride (Cl).

Table 6: Chloride.

SI Units	WHO Standard	Quality Standard			
		Good	Acceptable	Poor	Unacceptable
mg/L	<200	<100	101-200	201-600	>600

Three out of the 63 samples tested for chlorine borehole sample quality standards were found to be of poor quality as they exceeded the acceptable standards.

5.2.2 Fluorides (F).

Table 7: Fluoride.

SI Units	WHO Standard	Quality Standard			
		Good	Acceptable	Poor	Unacceptable
mg/L	<1,5	<0,7	0,71-1	1,1-1,5	>1,5

Some samples had unacceptable and poor-quality values with majority being good and acceptable.

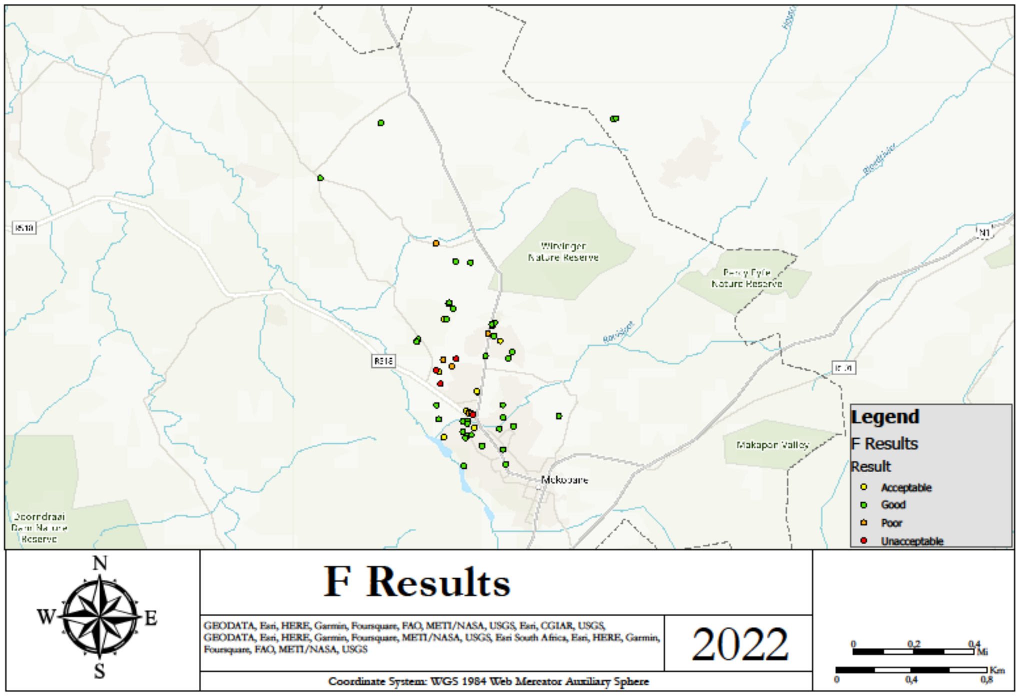

Figure 4: Map showing boreholes with varying Fluoride results (Source: Researchers).

5.2.3 Sulphates (SO4).

The Sulphates were found to be within the ideal quality parameter therefore categorising the water to be of good quality standard.

Table 8: Sulphates.

SI Units	WHO Standard	Quality Standard			
		Good	Acceptable	Poor	Unacceptable
mg/l	<400	<200	200-400	401-600	>600

5.2.4 Nitrate + Nitrite (NO3 + NO2).

Nitrite +Nitrite appear to be a serious water quality problem which indicates poor and unacceptable water quality.

Table 9: Nitrate + Nitrite.

SI Units	WHO Standard	Quality Standard			
		Good	Acceptable	Poor	Unacceptable
mg/L	<10	<6	6,1-10	10,1-20	>20

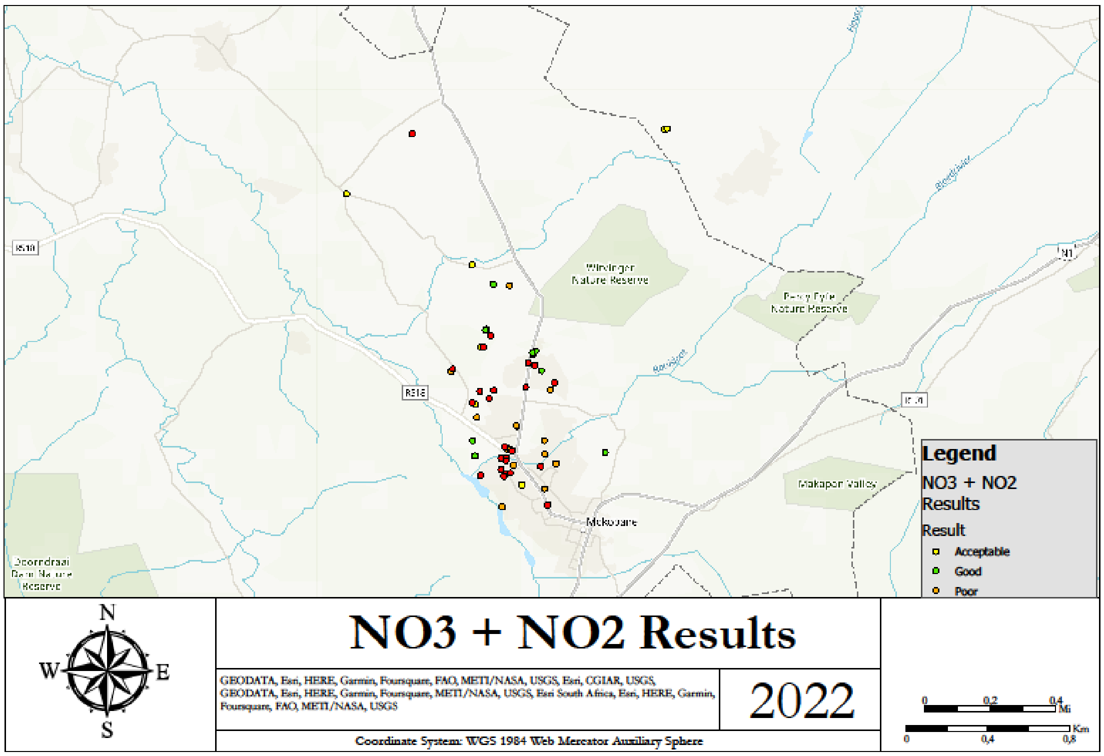

Figure 5: Map showing boreholes with varying NO3 and NO2 results (Source: Researchers).

5.3 Cations

5.3.1 Calcium (Cl)

The calcium parameters were found to be of good quality on most of the borehole samples with a few acceptable.

Table 10: Calcium

SI Units	WHO Standard	Quality Standard			
		Good	Acceptable	Poor	Unacceptable
mg/L	<150	<80	81-150	151-300	>300

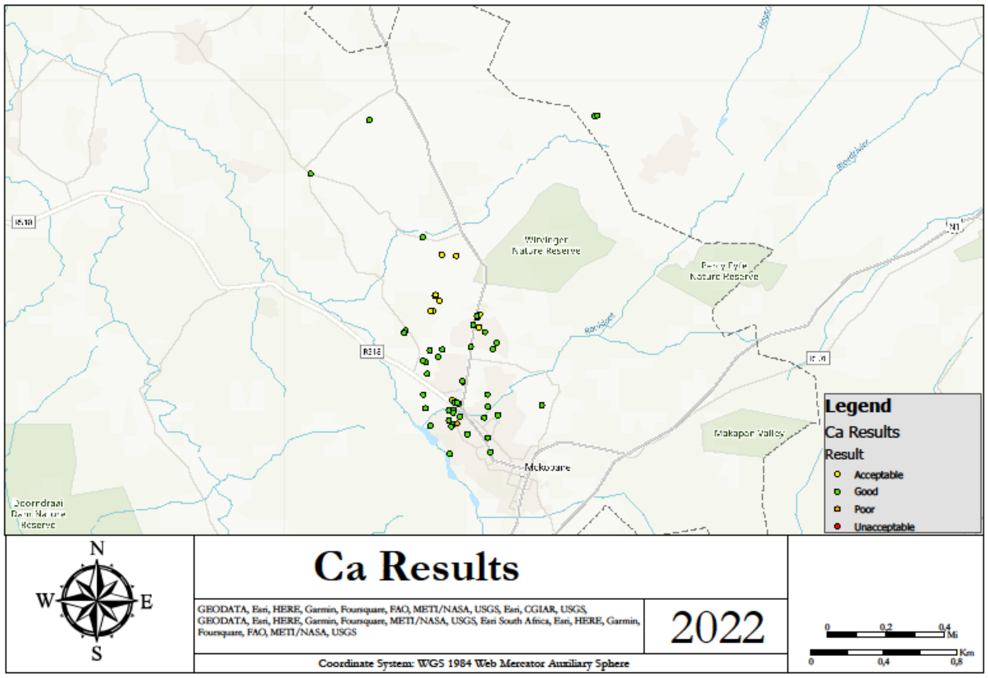

Figure 6: Map showing boreholes with varying Ca results (Source: Researchers).

5.3.2 Magnesium (Mg)

Samples were found to have alarming high concentration of Mg.

Table 11: Magnesium

SI Units	WHO Standard	Quality Standard			
		Good	Acceptable	Poor	Unacceptable
mg/L	<70	<30	31-70	71-100	>100

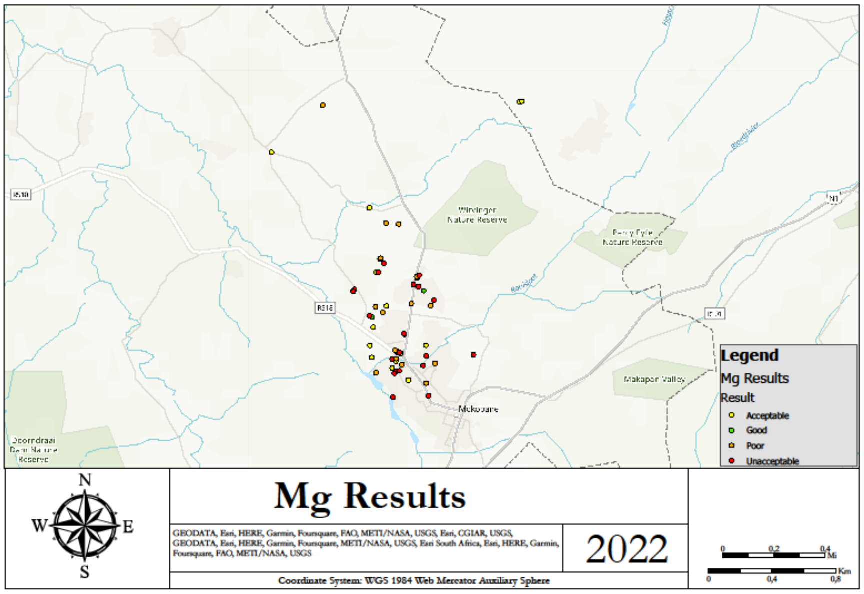

Figure 7: Map showing boreholes with varying Mg results (Source: Researchers).

5.3.3 Sodium (Na)

A few samples had poor quality value standard with the majority being acceptable and good.

Table 12: Sodium

SI Units	WHO Standard	Quality Standard				
		Good		Acceptable	Poor	Unacceptable
mg/L	<200		<100	101-200	201-400	>400

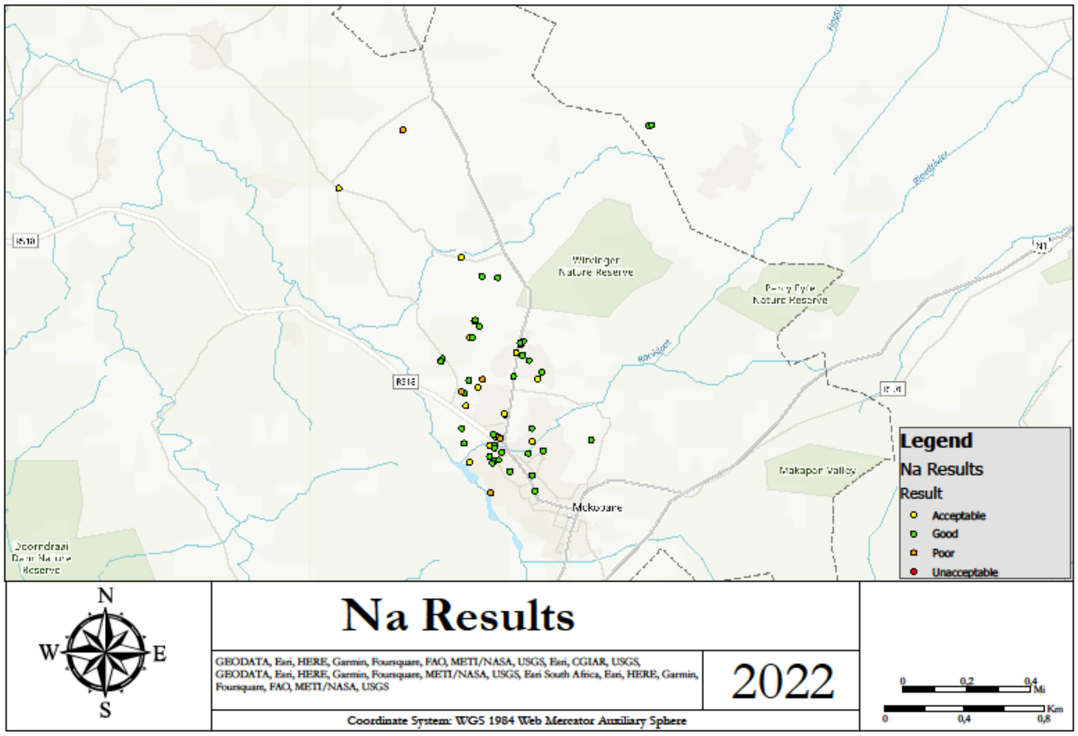

Figure 8: Map showing boreholes with varying Na results (Source: Researchers).

5.3.4 Potassium (K)

All samples were found to be of good quality standard.

Table 13: Potassium

SI Units	WHO Standard	Quality Standard			
		Good	Acceptable	Poor	Unacceptable
mg/L	<50	<25	26-50	51-100	>100

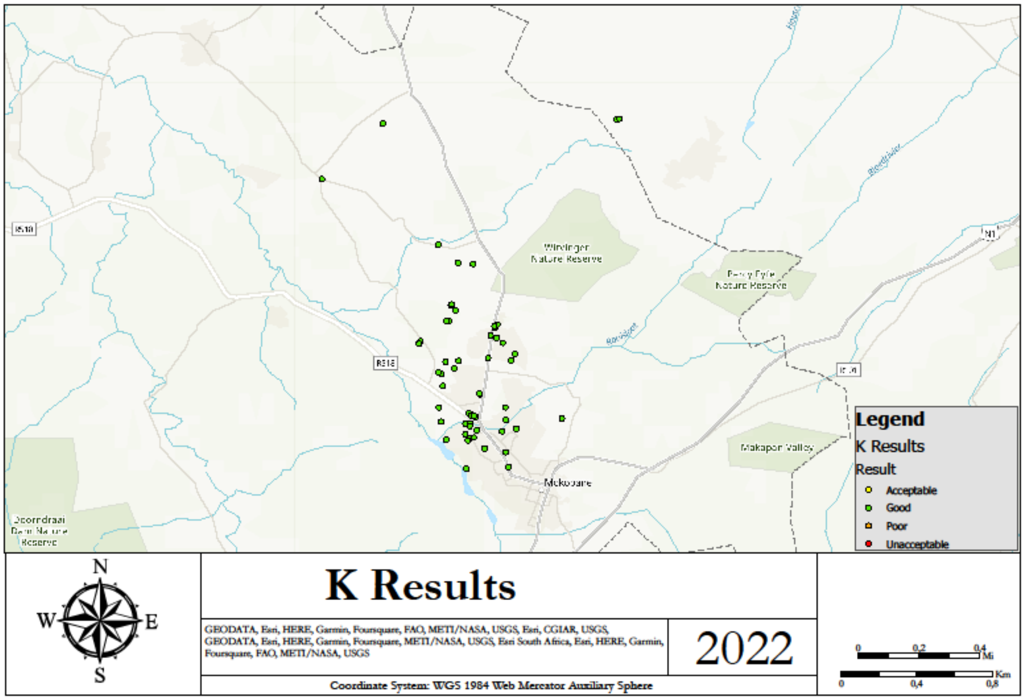

Figure 9: Map showing boreholes with varying k results (Source: Researchers).

6.Conclusion

The study area is home to a new mine which made it difficult to assess the impact mining activities in the area has had on the current water quality in the area. Another factor that made it hard to determine the impact of mines in the study area is access to previous data on the water quality making it hard to compare the current results to previous data. However, based on previous literature, similar researchers and the results received from sample testing, there are trends that show a relationship between results found and the impact geology has on water quality standards. High concentration of Fluorides indicates that the rocks formations which affects water flows affects water quality by increasing fluoride found in groundwater supply. It's recommended that Mogalakwena Municipality needs to monitor public boreholes in the area and upload results on ground water assessment for easier access on information, for the people to know the condition of the water they receive.

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