

## Water Pollution And Its Impact On The Environment

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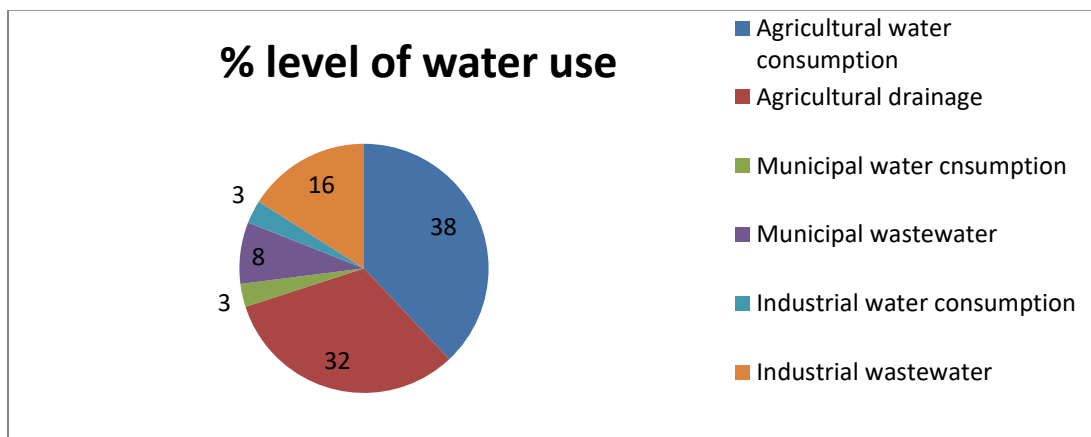
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**Abstract** - This study was done to assess the pollution of Elands River using both chemical and microbiological methods. The pollution index of the river revealed that the concentration of most pollutants downstream is more than 50% of the upstream concentration. The natural sources of the pollution in Elands River are the weathering of geological formations; whereas the anthropogenic sources are agriculture; Municipal WWTW and direct deposit of waste into the river. The natural sources of pollution contributed towards chemical pollution; whereas the anthropogenic sources contributed both chemical and microbiological pollution. The Elands River is hypertrophic downstream of the Rooiwal WWTW; however the current physiochemical state of the River warrants its ability to be used for safe irrigation in agricultural practices. The current microbiological state of the River does make it harmful for human consumption especially as drinking water; however, the water should be treated prior to use to inactivate the bacteria present in the water. The compilation of the various contaminants in the river were elucidated at the end of the study.

**Keywords:** Environmental studies, Water pollution, Elands River, South Africa, Water analysis.

### I. Introduction

Water Pollution is the phenomena whereby unwanted materials enter a water body and contaminate it [1]. Water Pollution may be caused by natural or anthropogenic causes. The pollutants are normally suspended solids, silt, pathogens, and soils, erosion particles from river banks, cosmetics, sewage materials, emissions, and construction debris. These pollutants contaminate the water and may include Toxic substances, carcinogenic chemicals, organic matter and heavy metals [2]. The biological, physical and chemical pollution of surface water is a global phenomenon and there is great interest in it [3]. Most anthropogenic activities that utilise water will ultimately produce wastewater (**Figure 1**); and the quantity of wastewater produced increases as the demand for water grows [4]. Three largest producers of waste water globally have been identified as agriculture, industry and municipalities; with agriculture producing 6%, industry producing 16% and municipalities producing 8% waste water [4], [5].



**Figure 1:** Global water consumption and waste water production by major water use sectors [4], [5].

The challenge with waste water is that a large amount of it is discarded into the environment as it is and no pre-treatment is performed. An average of 30% of wastewater that is not treated is released into the environment in developed countries and over 90% of wastewater that is not treated is discarded into the environment in developing countries. The discharge of untreated waste water is a key cause of global water pollution. [4], predicts that the global water demand will increase by a great deal over the next few decades as a result of increased urbanisation, agricultural, and industrial activities. The development of informal settlements as a result of urbanisation is also contributing greatly to the generation of wastewater.

Rivers play a vital role in surface water pollution as they collect waste water from industries, municipalities as well as water from agricultural activities. Contaminants that enter rivers will not only contaminate river water but river bed sediment too due to the continuous adsorption and desorption process between water column and bed sediment [3]. Sediment can act as a storage facility for water contaminants and can contain elevated levels of contaminants; for example sediment can contain from 100 to 1000 times more microbial load than their overlying water [6], [7]. Microorganisms can be re-suspended by means of activities such as boats, storms, or high winds [7], [8].

The Elands River runs through the Tshwane Metro of Gauteng Province and named after the prolific vervet monkeys that inhabited the area when the first settlers arrived in the Fountains Valley [9]. The Bon Accord Dam was built across Elands River in the north of Pretoria in 1925 to supply irrigation water to crop farmers in the region. Agriculture, power generation and waste water treatment are some of the activities that take place on the banks of the Elands River. Urban and rural communities are found to be living near the Elands River. Sources of Elands River pollution include water waste treatment plant effluent, power station effluent, agricultural runoff and effluent, urban and rural runoff [10]. Elands River is a prolific river that traverses areas of Pretoria, Gauteng. Effluent from many anthropogenic sources is discharged into the river [9]. This includes effluent from 4 Waste Water Treatment Works (WWTW) [10]. The challenge that the WWTW are experiencing is that with rapid urbanisation. Therefore it is important to study the chemical pollution on the Elands River. This research aim is to develop a comprehensive understanding of the physical, chemical and biological pollution of the Elands River water in near the Rooiwal WWTW

## 2. Literature review

Recent studies on the Elands River place a large focus on the effects of the Elands River Pollution on human wellbeing and do not describe the impact of pollution on the aquatic environment [6],[7],[11]; therefore it will be important to study the impact of the Elands River pollution on the aquatic environment. A large number of recent South African water quality studies have focused on eutrophication, sedimentation, salinization, urban runoff pollution, acid mine drainage and acidification, allowing for these issues to be classified as priority water management issues, while there is a gap in the understanding of issues such as dissolved oxygen and organics, pathogens and agrochemicals; therefore there is a need for more research on these topics [8].

Natural factors and anthropogenic activities both contribute towards river water pollution. The contribution of natural factors and anthropogenic activities is at both the river and watershed scale [1]. The anthropogenic pollution will either come from point sources or non-point sources. The pollution from natural factors will normally come from non-point sources. Both the anthropogenic and natural factors will have an effect on the river. Many households and farmers rely on surface waters for their daily activities. However, they can easily be polluted by non-point source (NPS) or point sources. As illustrated in **Figure 2**, NPS are the more prolific polluters as they are responsible for more than 60% of river water pollution.

NPS of pollution include animal faeces, faulty septic and sewage systems, storm water drainage and urban run-off. NPS are more difficult to recognise, put a figure on and explain than point sources as illustrated by Wright & Nebel [13]. Point sources include municipal WWTW, and livestock handling drainage. Fertilisers may either be chemical or organic. Chemical fertilisers mainly contain nitrates, phosphates and potash. Organic fertiliser is manure and also contains high levels of nitrates and phosphates [3]. The BOD of rivers is caused by 2 counteractive mechanisms organic pollutant loading and natural cleaning capabilities of rivers [4]. Organic pollution depletes the dissolved oxygen (DO) content of aquatic environments while breaking down organic matter. The amount of oxygen required for the total breakdown of organic matter present is referred to as biochemical oxygen demand (BOD); therefore BOD is an indication of organic pollution intensity [5]. Chemical Oxygen Demand (COD) can also be used to establish the amount of oxygen that would be reduced from an aquatic body due to bacterial activities.

Scientists have been studying the occurrence of faecal bacteria in water environments ever since 1952 [14]. They investigated the origins of *E. coli* pathogens in riverbed sediment, their dispersion over time, and lifespan. They demonstrated that non-pathogenic strains of *E. coli* lived longer in sediment than in the overlying water proving that *E. coli* can overwinter in sediments [7]. It was also demonstrated that the pathogens have a high preference for sediments and high natural carbon levels even in extreme temperature conditions. Various researches have shown that it is possible to have *Salmonella* existing in river sediment while not existing in water above [9]. Storms cause sediment particles to mix with the overlying water increasing the amount of *Salmonella* in the water column [2], [15].

The Elands River is located within the Apies-Pienaars River (A23) tertiary-catchment area. This region has a high population rate which is dense due to the City of Tshwane [13]. Most of the water required by the city is sourced from the Vaal River System; however, four sewage treatment plants are in close proximity to the River. The Rooiwal Water Waste Treatment Works (WWTW), located 8.4 km north of Bon Accord Dam, releases 100 million litres of treated sewage water into the Elands River per day. Storm-water from the city and the river is also discharged into the Elands River [4], [8]. The sites were sampled every two weeks for a month and a half. The site localities and site details are presented in Table 1 and the parameters analysed are presented in Table 2.

**Table 1:** Water Quality Sampling sites

Site Id	Site Name	Distance from Site	GPS Coordinates
AP1	Upstream of Olifants River	3.9 Km	24°55'27"S 29°20'45"E
EF1	Crocodile River (West)	2.1 Km,	24°17'18"S 27°31'8"E
AP2	Downstream of Crocodile River (East)	4.7 Km	20°43'21"S 29°20'45"E

### 3. Materials And Methods

Sterile 1 liter plastic bottles, Sterile 500g plastic containers, Augar, Coolerbox, Ice, Water samples, Hatch Lange Probe, filter papers, Analytical balance, Laboratory oven, Aquakem Konelab discrete analysers, Agilent 5110 Inductive Coupled Plasma Optical Emission Spectrometry (ICP-OES), Filter flask, Rubber stopper, Stainless steel base, Membrane filter, Forcep, Locking ring, Funnel, Beakers, Vacuum pump, Petri dishes, Endo agar, Laboratory oven, Original culture, Broth, Test tubes, Glass spreader.

#### 3.1. Procedure

Sterile one litre plastic sample bottles were used to collect grab river water samples aseptically at the sampling site, and the cap replaced immediately. The sample bottles were labelled and stored on ice to maintain lowest temperature possible. Augar was used to collect sediment samples. Auger was inserted into sediment at a 0-20° angle to the vertical, rotated and slowly withdrawn and transferred into a container. This was repeated 3-4 times at all sampling sites AP1 and AP2 to collect a composite sample. Sediment was kept in a container and stored on ice to maintain lowest temperature possible. The water and sediment samples were then delivered to Meriux Nutriscences Laboratory (Midrand-South Africa), for 16s rRNA sequencing and Regen Waters Laboratory for chemical and microbiological analysis (results not included).

pH and electrical conductivity were measured in situ at each site using the Hatch Lange Probe (Germany). Suspended solids were determined by filtration, measurement and calculation. At Regen Waters Laboratory (Witbank-South Africa), the concentrations of nutrients (Chloride, Fluoride, Nitrate, Nitrite, Ammonia, Ortho-Phosphate) in water samples were determined using the Aquakem Konelab discrete analysers by Thermo-Scientific (South Africa). The concentration of *E. coli*, Faecal Coliforms and Total Coliforms in water samples was determined using the SANS 5221 membrane filtration method. The concentrations of metals (sodium, potassium, calcium and magnesium) in water samples were determined using the Agilent 5110 Inductive Coupled Plasma Optical Emission Spectrometry (ICP-OES).

## 4. Results

### 3.1. Pollution Index (PI):

The average downstream water quality was compared to the average upstream water quality (Table 2). The Pollution Index (PI) was determined based on the ratio between downstream and upstream sample results. A PI ratio of less than 1.5 means that concentrations are less than 50% higher at the downstream site compared to upstream and these were highlighted in green. A PI ratio of 1.5 to 5 means that concentrations are between 50 and 100% higher at the downstream site compared to upstream and these were highlighted in orange. A PI ratio of above 5 means that concentrations are more than 100% higher at the downstream site compared to upstream and these are highlighted in red.

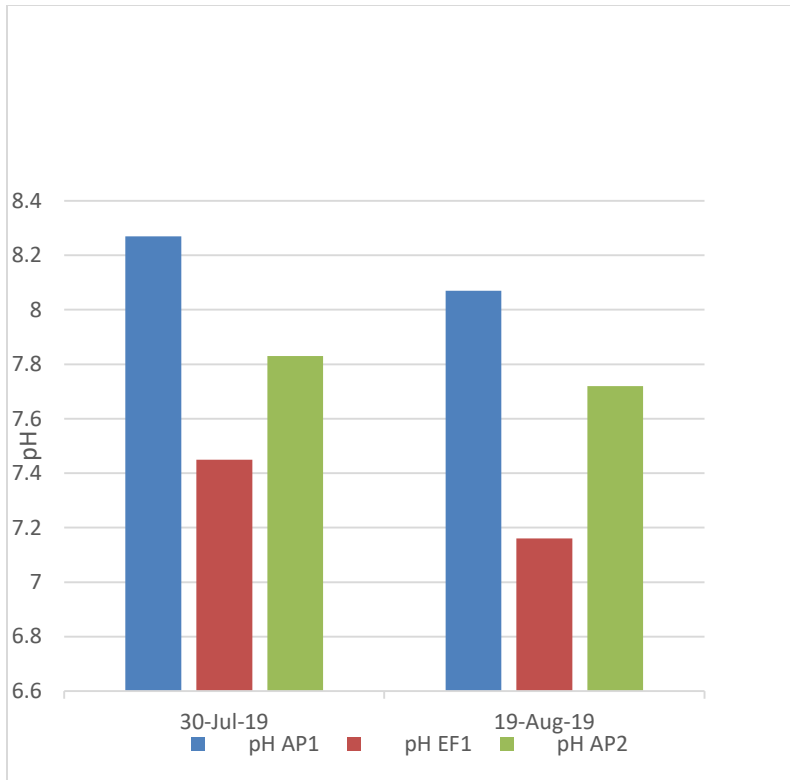
**Table 2:** Comparison of water quality properties Upstream (AP1) and Downstream (AP 2) Rooiwal WWTW

ANALYSIS RESULTS mg/l	AP 1 (AVE)	AP 3 (AVE)	Pollution Index
<i>Escherichia Coliform Per/100ML</i>	364.0	2420.0	6.6
<i>Total Dissolved Solids</i>	308.0	432.0	1.4
<i>Suspended Solids</i>	4.6	46.6	10.1
<i>Conductivity (mS/m)</i>	55.2	85.7	1.6
<i>4 Hours Oxygen Absorbed</i>	3.4	13.9	4.1
<i>Chemical Oxygen Demand</i>	16.0	97.0	6.1
<i>Nitrate - NO<sub>3</sub> as N</i>	0.9	1.3	1.5
<i>Nitrite - NO<sub>2</sub> as N</i>	0.1	0.8	12.8
<i>Ortho - Phosphate - PO<sub>4</sub> as P</i>	0.1	1.9	34.5
<i>Chlorides as Cl</i>	38.7	60.0	1.6
<i>pH - Value (pH Units)</i>	8.2	7.8	1.0
<i>Calcium as Ca</i>	41.2	39.8	1.0
<i>Magnesium as Mg</i>	23.1	18.4	0.8
<i>Sodium as Na</i>	36.5	84.2	2.3
<i>Potassium as K</i>	6.4	13.1	2.1

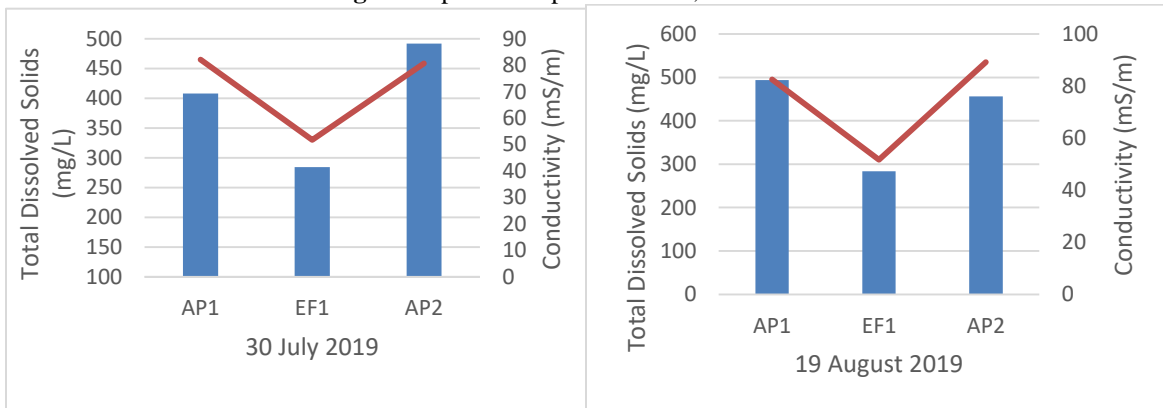
The dominant highlighted colours on Table 2 are orange and red; which indicates that the concentration of most pollutants downstream is more than 50% of the upstream concentration. Therefore the Rooiwal WWTW and surrounding activities have a significant adverse impact on the river.

### 3.2. Physiochemical Water Quality

The pH of the Elands River samples range between 7.8 and 8.3 (Figure 2). The pH of the Rooiwal WWTW effluent is almost neutral at 7.45. The EC of the Elands River water follow the same trend as the TDS; with the downstream site having higher values than the upstream sites.

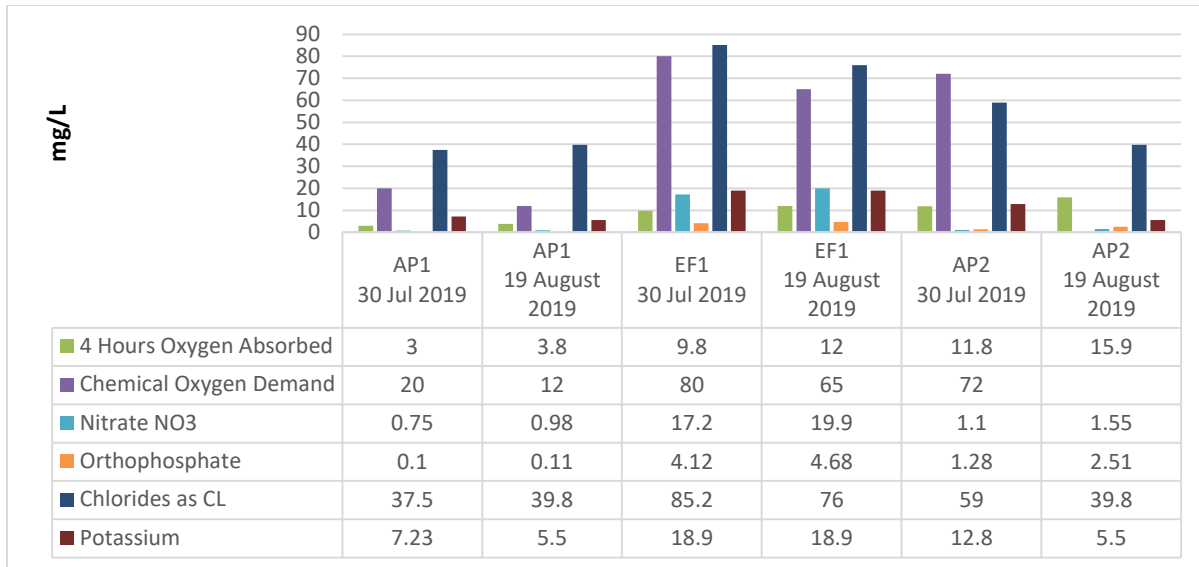


**Figure 2:** pH of sample sites AP1, AP2 and EF1



**Figure 3:** Physiochemical properties of sample sites AP1, AP2 and EF1

COD is a measure of organic pollution intensity. COD was higher at the downstream site. Nitrates NO<sub>3</sub><sup>-</sup> follow a similar trend as the COD with higher concentrations at the downstream and the highest concentrations from the Rooiwal WWTW effluent (Figure 3).



**Figure 4:** Chemical properties of sample sites AP1, AP2 and EF1

The average Orthophosphates PO<sub>4</sub><sup>3-</sup> concentration of the river is 0.055 mg/L at the upstream site and 1.895 mg/L at the downstream site. Chloride and Potassium concentrations of the river water are higher downstream to the Rooiwal WWTW and significant concentrations are observed in the effluent of the Rooiwal WWTW [3]. The physiochemical properties of Elands River water upstream (AP1) of Rooiwal WWTW complies with the SANS 241 drinking water standard. The physiochemical properties of Elands River water downstream of Rooiwal WWTW (AP2) does not comply with the SANS 241 drinking water standard due to the high concentrations of ammonia in the water which have been introduced by the effluent from Rooiwal WWTW (Figure 3).

### 3.3. Microbiological Water Quality

**Table 3:** Comparison site AP1 microbiological properties against SANS 241 drinking water standard

Date	AP1			Heterotrophic Plate Count Per 1.0 ML
	Total Coliform Bacteria Per/100ML	Faecal Coliform Per/100ML	Escherichia Coliform Per/100ML	
Standard Limits	≤10	NIL	NIL	≤1000
2-Jul-19	≥2420	60	41	1793
30-Jul-19	325	NIL	NIL	800
19-Aug-19	≥2420	850	687	1488

The significant difference in microbiological pollution between the samples collected upstream of Rooiwal WWTW and downstream WWTW indicates that the WWTW has an adverse effect on the river (Table 3). However due to the presence of a significant amount of microbiological agents in the Elands River upstream of the Rooiwal WWTW is not the only source of microbiological pollution of the Elands River; there must be other sources of microbiological agents upstream of Rooiwal WWTW. The identification test proved that the dominant bacteria in the water and sediment samples were *E. coli*. *E. coli* is normally utilised as microbial indicators for possible faecal contamination as it commonly occurs in faeces from humans and animals as reported in literature [3].

## 4. Discussion

### 4.1. Elands River Pollution at the Upstream site (AP1)

The dominant highlighted colours on the result (Table 2) are orange and red; which indicates that the concentration of most pollutants downstream is more than 50% of the upstream concentration. The presence of E.coli upstream (AP1) shows that there is E.coli pollution is not only contributed by the Rooiwal WWTW but other sources of E. coli pollution are also present in the area. COD is a measure of organic pollution intensity and the levels of COD range between 12 and 20 mg/l (Figure 4). These levels are fairly low and therefore correlate with the levels of E. coli at the site. There are no guidelines for levels of E.coli in aquatic ecosystems as it is not pathogenic to fish; however the presence of Ecoli serves as an indication of human and animal waste in the river [5], [16].

There is a South African Water Quality Guidelines for Recreational use; based on the full-contact recreational guidelines the water at AP1 is unsuitable for swimming and poses a risk of gastrointestinal illnesses. Based on intermediate contact recreation this water is suitable for activities such as canoeing and water skiing [16]. The TDS of the Elands River Upstream ranges between 284 and 332; with chloride, calcium, magnesium and sodium being the most dominant elements in the water. The average Orthophosphates PO<sub>4</sub><sup>3-</sup> concentration of the river is ranges between 0 and 0.11 mg/L at the upstream site. The values are below the hypertrophic threshold value of 0.13 mg/L; therefore the Elands River Upstream fluctuates between the state of oligotrophication and eutrophication. The fluctuations may be as a result of variation in the flow of agricultural run-off towards the river [3]. The nitrate ranges between 0.75 and 0.98 mg/L .Nitrates NO<sub>3</sub><sup>-</sup> follow a similar trend as the COD with higher concentrations downstream.

### 4.2. Elands River Pollution at the Downstream Site (AP2)

There average concentration of E.Coli at the downstream site is 2420 mg/L. This value is significantly higher than that at the upstream site. The elevated levels of E.coli can be attributed to the direct input of Rooiwal WWTW effluent into the river. Based on the full contact and intermediate contact guidelines of the South African Water Quality Guidelines for Recreational use [16]. The Orthophosphates PO<sub>4</sub><sup>3-</sup> concentration of the river is downstream ranges between 1.28 and 2.51 mg/L. The values are significantly higher than the hypertrophic threshold value of 0.13 mg/L; therefore the Elands River downstream is hypertrophic as a result of effluent input from the Rooiwal WWTW. The Orthophosphates PO<sub>4</sub><sup>3-</sup> concentrations of the effluent ranges between 4.12 and 4.68 mg/L due to the use of phosphate in the WWTW processes. The nitrate ranges between 1.1 and 1.55 mg/L . The nitrates levels in the effluent from the Rooiwal WWTW are also very high with an average concentration of 18.3 mg/L as a result of the use of nitric acid at the Rooiwal WWTW as according to Ekwanzala et al.. [7]

### 4.3. Agricultural Use of Elands River Water

According to DWAF guidelines [16], irrigation water can be grouped into three classes: pH < 6.5, pH between 6.5 and 8.4 and pH > 8.4. The Elands River water is therefore within the water quality target for irrigation; which commonly occurs both upstream and downstream. The TDS of the Elands River water ranges between 284 and 408. Literatures suggests that a TDS of less than 450 mg/L is optimum for irrigation water indicating that the water from the river is well below the threshold [12], [13]. The TDS of the Rooiwal WWTW effluent is higher than that of the river water and there is an increase in the TDS downstream due to the effluent discharge. The isolation of bacteria E coli, Klebsiella pneumonia, Cronobacter sakazakii and Citrobacter freundii; in the river water and sediment demonstrated the microbiological contamination [3], [6], [7]. Therefore, there are higher chances of exposure to these pathogens, meaning that the use of Elands River water for domestic purposes should be avoided.

### 4.4. Domestic Use of Elands River Water

The results shows that physiochemical components of the Elands River upstream (AP1) of Rooiwal WWTW is relatively unpolluted and complies with the physiochemical limits set out in the SANS 241 Drinking Water Standard [16]. The introduction of high concentrations of ammonia by the Rooiwal WWTW results in the downstream portion of the river being non-compliant with the physiochemical limits of ammonia that are set in the SANS 241.

## 5. Conclusion

The Elands River is polluted both chemically and microbiologically. The pollution index of revealed that the concentration of most pollutants downstream is more than 50% of the upstream concentration. The natural source of the Elands River is the weathering

of geological formations; whereas the anthropogenic sources of the Elands River are agriculture, municipal WWTW and direct deposit of waste into the river. As natural sources of pollution contributed towards chemical pollution, anthropogenic sources contributed to both the chemical as well as the microbiological pollution.

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