Water Practice & Technology

Water Practice & Technology Vol 18 No 5, 1011 doi: 10.2166/wpt.2023.053

Impacts of illegal solid waste dumping on the water quality of the Mthatha River

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ABSTRACT

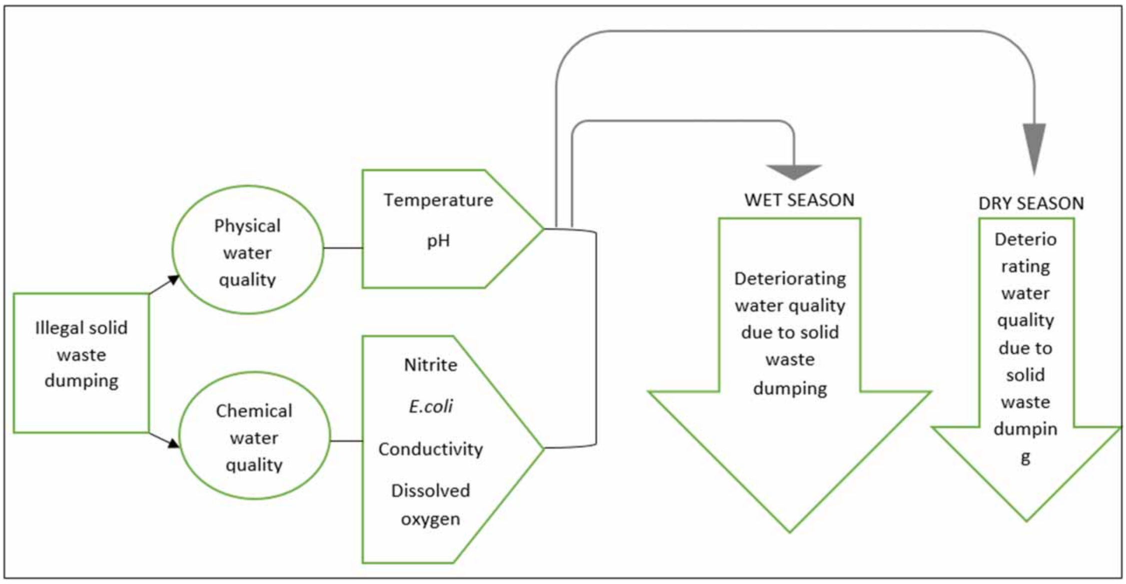
The world faces problems such as improper waste disposal that have spread to include disposal near water bodies. It is getting difficult to find fresh water everywhere. Given that surface sources provide around one-third of the world's drinking water needs, their contamination exacerbates the issue. This paper aims at evaluating the impacts of solid waste on water quality along the Mthatha River. During the rainy and dry seasons of 2021, Hanna probe instruments were used to assess the physicochemical quality of water before and after identified illegal dump sites. To compare the measured mean values of water quality parameters data were analysed using ANOVA in SPSS version 22. In terms of temperature, dissolved oxygen, pH, nitrite, conductivity, and *Escherichia coli*, the water quality in the sampling points after the illegal dump sites revealed deterioration, which was more severe in the rainy season and moderate in the dry season. The study's findings suggest that illegal dump sites along water bodies negatively impact the water quality. Diverse research on water pollution shows that declining water quality endangers aquatic species and is unsafe for human consumption. This paper recommends strengthening of laws against improper waste handling, and frequent waste collection to prevent contamination of water bodies.

Key words: illegal dump sites, Mthatha River, physicochemical parameter, solid waste, water quality

HIGHLIGHTS

- Illegal dumping of solid waste along the water bodies.
- Waste from illegal dump sites contaminate the river, especially in the wet season.
- Aquatic species get threatened and water becomes unsafe for human consumption.
- Enforcement of laws against improper waste handling is suggested to prevent water pollution.

GRAPHICAL ABSTRACT



INTRODUCTION

The scarcity of freshwater is one of the main problems the world is currently experiencing. The supply of drinking water worldwide is derived from one-third of the total surface water sources such as rivers, dams, lakes, and canals (Edokpayi *et al.* 2017). Surface water presents an important source of freshwater; however, the volume of water available to all life from these surface water bodies is constantly declining. This is because of a variety of factors, including anthropogenic activities and the greenhouse effect (Nwaneri *et al.* 2018). In addition to reduced volume, freshwater from the surface water bodies is reduced in quality also, due to various pollutants as a result of human activities such as washing, bathing, and irrigation disposal, if disposed along or into the water body. Waters above and below the ground may both be contaminated. The risk of flooding may also increase if waste is deposited into watercourses, which could alter proper water flow. Illegal waste dumping on riverbanks endangers the habitats of the creatures residing there (Malinowski *et al.* 2015).

The National Environmental Management Waste Act (NEM: WA) 59 of 2008 is a piece of legislation that aims to improve waste management procedures while also preventing pollution and ecological damage. This act encourages and guarantees the efficient provision of waste services (Molewa 2013). In Mthatha, this regulation is partially in effect especially in the informal settlements as people do not have proper material for dumping their waste, and as such, indiscriminate random waste is rampant in many places. In the middle course of the river, there is a lot of solid waste that has been dumped illegally (Buso *et al.* 2014). Certain places in the middle course are hotspots for this research.

On the other hand, the National Water Act (NWA) 36 of 1998 was designed to ensure that the country's water resources are protected, used, developed, conserved, managed, and controlled in ways that take into account, among other things: promoting equitable access to water; redressing the effects of past racial and gender discrimination; promoting the efficient, sustainable, and beneficial use of water in the public interest; facilitating social and economic development (Africa 1998). In the instance of the Mthatha River catchment, there are some shortcomings in carrying out this act, thus the habitat of aquatic species is being threatened by illegal dumping. Poor waste management is prevalent in Mthatha, particularly along the urban portion of the Mthatha River's middle course. People irresponsibly dispose of their waste near the river due to growing urbanization and informal settlements, which could have a detrimental impact on the river's water quality. The middle course of the Mthatha River has a congested population as it is the place that surrounds the town (Buso *et al.* 2014). River water is known for its ability to replenish itself as it flows, but the extent of this replenishment is not fully understood, especially along the Mthatha River middle course, where many dry dump sites of solid waste due to congested populations exist. This study brings an important connection to the anthropogenic activities that affect water quality through the illegal dumping of solid waste along waterbodies. Water that has not fully replenished itself can be used by humans, unaware that it has not yet finished replenishing itself. Thus, there is a need to fully understand the dynamics of the problem and find appropriate pathways for dealing with the problem. This paper aims at assessing the impacts of solid waste dumped along the river on the water quality of the Mthatha River.

This study is situated within the Soil and Water Assessment Tool (SWAT) model, because it analyses river water quality dynamics in relation to pollution from illegal dump sites. This model is a river basin scale model for water resource management and is used to measure the influence of land management practices in the watershed and in assessing soil and water (Olowe 2018). Likewise, this study focuses on the water aspect, assessing water quality as a result of solid waste from illegal dump sites.

MATERIALS AND METHODS

This study was conducted in King Sabata Dalindyebo, a local municipality in the Eastern Cape of South Africa where the Mthatha River catchment is found, as can be seen in Figure 1. The focus was on the middle course of the Mthatha River where the urban side of Mthatha exists and there is a congested population. Mthatha is an emerging urban city in South Africa with rapid urbanization in sub-Saharan Africa. It is the only town within 230 km of the Transkei region and the third-largest town in South Africa's Eastern Cape province. It serves as an economic and social hub for the eight regional towns with lower functional rankings as well as the nearby rural villages (Council 2017).

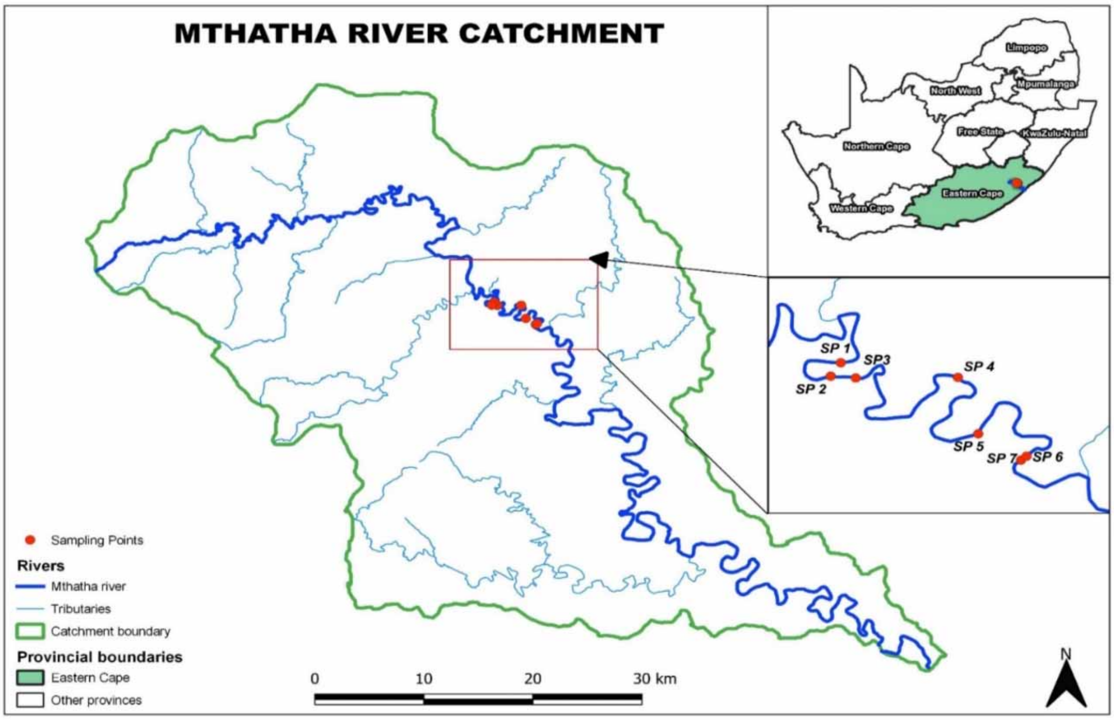


Figure 1 | Map of the study area and water quality sampling points.

For mapping of sources of waste (illegal dump sites), GPS co-ordinates were collected from the dump sites and were later coded to QGIS for visual presentation. To evaluate the impacts of solid waste along the river, water quality was tested. A sampling point preferably within 100 m before and after each illegal dump site was identified to test water quality. Water was tested three times in each sampling site for validity before and after each identified dump site of illegal solid waste to compare the quality before and after the dump site. This was also done to control the changes in water quality as a result of organic compounds and phytoplankton. The sampling was done for two seasons, namely the rainy and the dry season, to spot the differences and draw up conclusions about whether seasonality has a significant impact on the impacts posed by solid waste on water quality. For the rainy season, the data were collected in February 2021 and for the dry season, the data were collected in June 2021. The physical and chemical qualities of water in the Mthatha River were tested.

For physical quality, water temperature, color of the water, odor, and conductivity were measured. Water temperature and electrical conductivity were measured using Hanna probe instruments for water quality and were measured in all the sample points before and after the illegal dumping sites. Measurements were done three times in each sampling site to validate the results. Color of water and odor were measured through observations and comparison to the true (normal) color and true (normal) odor of water. For chemical quality, water pH, nitrite, and dissolved oxygen (DO) were measured. They were all measured using Hanna probe instruments for water quality in all the sampling points before and after the illegal dumping sites. Even on the chemical quality, measurements were done three times at each sampling point to validate the results. For detecting *E. coli*, water samples were taken from each sampling site during the dry and wet seasons to the WSU Pollution Laboratory for testing.

RESULTS

Figure 2 shows the distribution of illegal dumping sites in a polygonal shape, and how the water sampling points were chosen before and after these dumping sites.

As depicted in the map, illegal dumping sites are shown in the polygonal shapes and the sampling points for water quality before and after the illegal dumping sites. To examine the impacts of solid waste found in these illegal dumping sites on river water, water quality had to be tested. The sampling points had to be chosen before and after the illegal dumping sites to see the difference in water quality before and after the dumping site so that a comparison can be made, and a conclusion can be taken if the illegal dumping site affects water quality or not. Data were collected in the wet and dry seasons to check the effect of seasonality on the above-mentioned problem.

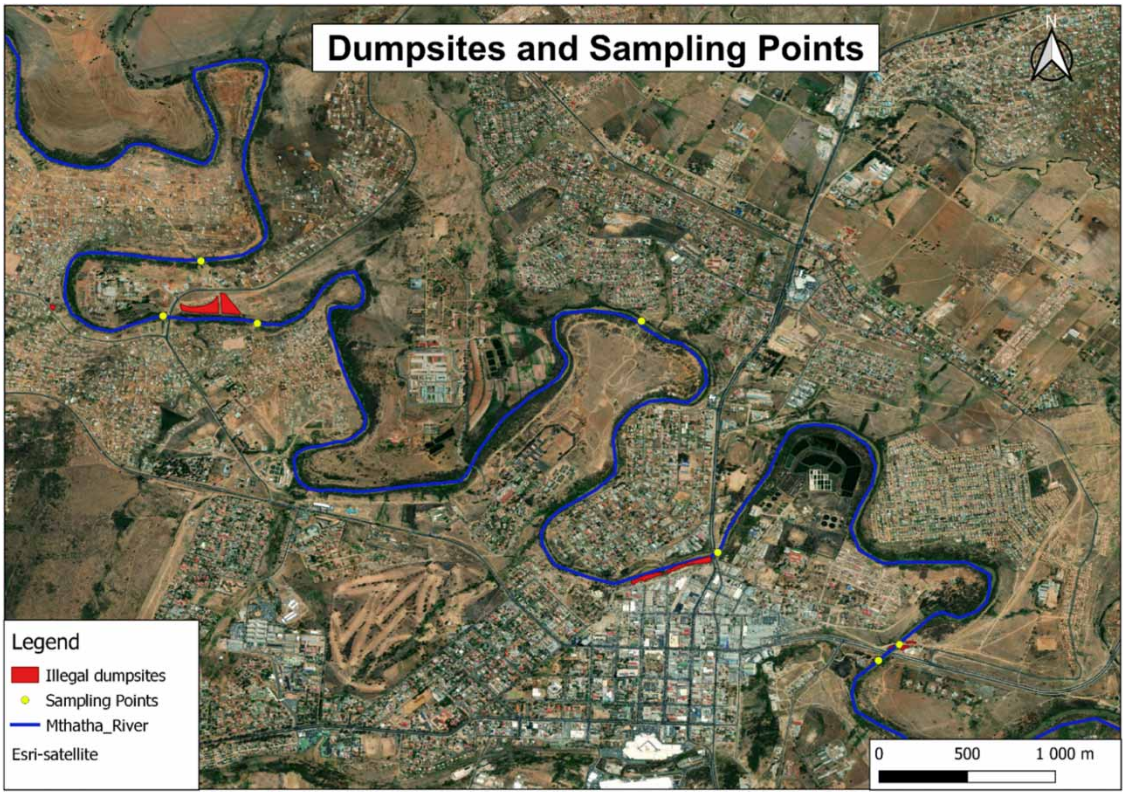


Figure 2 | Illegal dumpsites along the Mthatha River and water quality sampling points.

Table 1 shows water parameters and ANOVA descriptives in all seven points. For each parameter at every point, water samples were taken in triplicate to validate the readings. Seven instead of eight sites were sampled for water quality, this is because sampling point 2 was regarded as after the Slovo Park illegal dumping site and before the Polar Park illegal dumping site due to its location, it served almost to be in the center for both these illegal dumping sites.

Table 1 | Water parameters and ANOVA descriptives of the Mthatha River during wet and dry seasons of 2021

		Wet season (summer)				Dry season (winter)			
Water parameter	**Sampling site**	***N***	**Mean**	**Std. deviation**	**Std. error**	***N***	**Mean**	**Std. deviation**	**Std. error**
Temperature	Slovo Park (before)	3	25.300	0.8000	0.4619	3	16.3333	0.25166	0.14530
	Slovo Park (after), Polar Park (before)	3	25.400	1.5716	0.9074	3	16.4000	0.34641	0.20000
	Polar Park (after)	3	25.733	0.4041	0.2333	3	16.0333	0.25166	0.14530
	Norwood (before)	3	24.800	1.0583	0.6110	3	15.5333	0.20817	0.12019
	Norwood (after)	3	26.633	0.4933	0.2848	3	16.0000	0.55678	0.32146
	Downtown (before)	3	24.933	0.2517	0.1453	3	16.6000	0.45826	0.26458
	Downtown (after)	3	24.647	0.2082	0.1202	3	16.0000	0.55678	0.32146
	Total	21	25.181	0.9683	0.2113	21	16.1286	0.47132	0.10285
pH	Slovo Park (before)	3	7.687	0.1537	0.0888	3	7.1133	0.30989	0.17892
	Slovo Park (after), Polar Park (before)	3	8.347	0.1115	0.0644	3	7.2133	0.08145	0.04702
	Polar Park (after)	3	7.637	0.0666	0.0384	3	6.9300	0.07211	0.04163
	Norwood (before)	3	7.663	0.2403	0.1387	3	6.9300	0.06245	0.03606
	Norwood (after)	3	7.667	0.1021	0.0590	3	6.8367	0.01155	0.00667
	Downtown (before)	3	7.513	0.0777	0.0448	3	6.7800	0.01732	0.01000
	Downtown (after)	3	7.590	0.0917	0.0529	3	7.0867	0.04163	0.02404
	Total	21	7.729	0.2867	0.0626	21	6.9843	0.18370	0.04009
Nitrite	Slovo Park (before)	3	26.667	0.5774	0.3333	3	56.67	23.245	13.421
	Slovo Park (after), Polar Park (before)	3	4.667	0.5774	0.3333	3	7.00	1.000	0.577
	Polar Park (after)	3	43.667	3.5119	2.0276	3	18.00	9.165	5.292
	Norwood (before)	3	48.333	3.0551	1.7638	3	77.67	11.015	6.360
	Norwood (after)	3	58.000	7.0000	4.0415	3	62.00	12.490	7.211
	Downtown (before)	3	66.333	7.2342	4.1767	3	82.67	26.539	15.322
	Downtown (after)	3	68.667	7.6376	4.4096	3	95.00	32.419	18.717
	Total	21	45.190	22.1847	4.8411	21	57.00	35.386	7.722
Dissolved oxygen	Slovo Park (before)	3	7.520	0.4084	0.2358	3	9.1667	0.11372	0.06566
	Slovo Park (after), Polar Park (before)	3	7.810	0.2443	0.1411	3	9.0267	0.11060	0.06386
	Polar Park (after)	3	8.183	0.0208	0.0120	3	9.1367	0.06658	0.03844
	Norwood (before)	3	7.817	0.2146	0.1239	3	9.2467	0.08963	0.05175
	Norwood (after)	3	7.210	0.0500	0.0289	3	8.5167	0.09713	0.05608
	Downtown (before)	3	7.190	0.0520	0.0300	3	8.2600	0.09849	0.05686
	Downtown (after)	3	7.303	0.0115	0.0067	3	8.2533	0.16563	0.09563
	Total	21	7.576	0.3926	0.0857	21	8.8010	0.42875	0.09356
Conductivity	Slovo Park (before)	3	24.767	0.8505	0.4910	3	72.67	6.028	3.480
	Slovo Park (after), Polar Park (before)	3	28.067	0.4041	0.2333	3	67.67	17.616	10.171
	Polar Park (after)	3	28.233	0.8327	0.4807	3	75.33	2.082	1.202
	Norwood (before)	3	29.633	3.0551	1.7638	3	70.67	4.726	2.728
	Norwood (after)	3	36.600	9.1886	5.3050	3	77.67	4.041	2.333
	Downtown (before)	3	28.833	1.5631	0.9025	3	83.00	3.606	2.082
	Downtown (after)	3	33.400	3.4771	2.0075	3	88.67	2.082	1.202
	Total	21	29.933	4.9611	1.0826	21	76.52	9.416	2.055
E. coli	Slovo Park (before)	3	4,700	0.000	0.000	3	20	0.000	0.000
	Slovo Park (after), Polar Park (before)	3	12,860	0.000	0.000	3	120	0.000	0.000
	Polar Park (after)	3	12,940	0.000	0.000	3	500	0.000	0.000
	Norwood (before)	3	12,080	0.000	0.000	3	4,800	0.000	0.000
	Norwood (after)	3	16,700	0.000	0.000	3	8,420	0.000	0.000
	Downtown (before)	3	12,280	0.000	0.000	3	8,040	0.000	0.000
	Downtown (after)	3	15,700	0.000	0.000	3	8,240	0.000	0.000
	Total	21	12,465.71	3,659.094	798.480	21	4,305.71	3,813.781	832.235

In the wet season, the temperature trend depicts a slight increase of less than a degree in the mean values of the sampling points found after the illegal dump sites for all the sampling points, as shown in Table 1. It is only in Downtown where this slight increase was absent, instead, there was a slight decrease. The dry season's temperature trend showed either a slight increase or a slight decrease in the sampling sites after the illegal dumping sites as compared to those before the illegal dumping sites. In the Downtown sampling site after the illegal dumping site, a noticeable decrease of 0.6 °C in temperature can be seen.

In water pH, during the wet season, an increase in mean for all sampling points after the dump sites can be seen except for Polar Park (after) where a decrease in the mean values of the water pH can be seen. For the dry season, in all other sampling points, there is a slight increase in water pH after the illegal dump site except for Polar Park.

The trend of nitrite during the wet season revealed a decrease of 22 mg/L in the sampling point after Slovo Park which also serves as before Polar Park. After Polar Park's illegal dumping site, an increase of 39 mg/L was noticeable in the mean values of nitrite. Also, Norwood and Downtown showed an increase in their sampling points (after) average mean values as compared to their sampling points (before). For the dry season, the mean nitrite decreased from the sampling point after the illegal dumping site at Slovo Park, as well for Norwood. However, an increase in nitrite can be seen in the sampling point after the illegal dumping site at Polar Park and Downtown.

DO mean value for the wet season showed an increase of 0.29 mg/L in Slovo Park after the illegal dumping site as compared to the samples taken before the dumping site. It was the case as well for Polar Park and Downtown. In Norwood, a decrease of 0.607 mg/L in the mean values of DO was noticed for the samples taken after the illegal dump site compared to those taken before the dumping site. For the dry season, a decrease can be noticed in the DO mean value in all the sampling sites after the illegal dumping site except for Polar Park, where a slight increase can be seen.

Wet season's water electrical conductivity mean values at sampling points after the illegal dump sites showed an increase in all of them as compared to electrical conductivity for sampling points before the dump sites. On the other side for the dry season electrical conductivity's mean value, surprisingly a decrease of 5 μS/cm was noticed in the sampling site after the Slovo Park illegal dumping site, and an increase is noticed in the sampling site after the Polar Park illegal dumping site that is cleared. All other sampling sites after the illegal dumping site showed an increase in the electrical conductivity.

The wet season's average of *E. coli* depicts an increase in all sampling points after the illegal dumping sites. A high increase of 8,160; 4,620; and 3,420 cfu/100 mL, respectively, were recorded at Slovo Park, Norwood and Downtown sampling points. For the dry season, the average number of *E. coli* increased in all sampling points after the illegal dumping sites. A very high increase of 3,620 cfu/100 mL was recorded at Norwood as there is a high number of diapers in this area.

Table 2 illustrates Turkey's Honest Significant Difference (HSD) multiple comparisons for the water quality in all seven sampling points. *E. coli* did not appear in the results for HSD multiple comparisons.

For the wet season, water temperature shows no statistical difference for the sampling points before the dump sites and the sampling points after the dump sites, as they are all above 0.05. Based on that information, we, therefore, accept the null hypothesis (H_0) which states that there is no significant difference between the mean water quality variables before and after the illegal dump sites. Likewise, there is also no statistically significant difference in the temperature mean values for the dry season. We also accept the null hypothesis (H_0) and reject the alternative hypothesis (H_1).

A statistically significant difference in water pH was observed for sites between Slovo Park (before) and Slovo Park (after), as well as between Polar Park (before) and Polar Park (after) for the wet season as shown in Table 2. The values fall less than 0.5, implying that we reject the null hypothesis (H_0) and accept the alternative hypothesis (H_1), which states that there is a significant difference between the mean water quality variables before and after the illegal dump sites. For the water pH of Norwood and Downtown in the wet season, we accept the null hypothesis as there is no statistically significant difference in the pH values before and after the illegal dumping sites, in both these sites. In the dry season, there is no significant difference in water pH between before and after sampling points, meaning we accept the null hypothesis and reject the alternative hypothesis.

In the wet season, there is a statistically significant difference in nitrite values between Slovo Park before and after, as well as with Polar Park before and after. This means that for both these sites we reject the null hypothesis (H_0) and accept the alternative hypothesis (H_1). The significant difference is an indicator that nitrite increases after the illegal dump sites, meaning these dump sites harm water quality. For Norwood before and Norwood after, Downtown before and Downtown after, we accept the null hypothesis (H_0) as there is no statistically

Table 2 | Tukey HSD multiple comparisons of water quality during wet and dry seasons of 2021

Dependent variable	(A) Name of the site	(B) Name of the site	Wet season (summer) Mean difference (A–B)	Wet season (summer) Std. error	Wet season (summer) Sig.	Dry season (winter) Mean difference (A–B)	Dry season (winter) Std. error	Dry season (winter) Sig.
Temperature	Slovo Park (before)	Slovo Park (after), Polar Park (before)	−0.1000	0.6721	1.000	−0.06667	0.32660	1.000
	Slovo Park (after), Polar Park (before)	Polar Park (after)	0.6667	0.6721	0.948	0.36667	0.32660	0.911
	Norwood (before)	Norwood (after)	−1.8333	0.6721	0.162	−0.46667	0.32660	0.779
	Downtown (before)	Downtown (after)	0.4667	0.6721	0.991	0.60000	0.32660	0.547
pH	Slovo Park (before)	Slovo Park (after), Polar Park (before)	−0.6600*	0.1083	0.000	−0.10000	0.10417	0.955
	Slovo Park (after), Polar Park (before)	Polar Park (after)	0.7100*	0.1083	0.000	0.28333	0.10417	0.164
	Norwood (before)	Norwood (after)	−0.0033	0.1083	1.000	0.09333	0.10417	0.967
	Downtown (before)	Downtown (after)	−0.0767	0.1083	0.990	−0.30667	0.10417	0.113
Electrical conductivity	Slovo Park (before)	Slovo Park (after), Polar Park (before)	−3.3000	3.2349	0.941	5.000	6.226	0.981
	Slovo Park (after), Polar Park (before)	Polar Park (after)	−0.1667	3.2349	1.000	−7.667	6.226	0.871
	Norwood (before)	Norwood (after)	−6.9667	3.2349	0.376	−7.000	6.226	0.910
	Downtown (before)	Downtown (after)	−4.5667	3.2349	0.787	−5.667	6.226	0.965
Nitrite	Slovo Park (before)	Slovo Park (after), Polar Park (before)	22.0000*	4.1633	0.002	49.667	15.910	0.084
	Slovo Park (after), Polar Park (before)	Polar Park (after)	−39.0000*	4.1633	0.000	−11.000	15.910	0.991
	Norwood (before)	Norwood (after)	−9.6667	4.1633	0.299	15.667	15.910	0.949
	Downtown (before)	Downtown (after)	−2.3333	4.1633	0.997	−12.333	15.910	0.984
Dissolved oxygen	Slovo Park (before)	Slovo Park (after), Polar Park (before)	−0.2900	0.1628	0.579	0.14000	0.08955	0.706
	Slovo Park (after), Polar Park (before)	Polar Park (after)	−0.3733	0.1628	0.311	−0.11000	0.08955	0.872
	Norwood (before)	Norwood (after)	0.6067*	0.1628	0.029	0.73000*	0.08955	0.000
	Downtown (before)	Downtown (after)	−0.1133	0.1628	0.991	0.00667	0.08955	1.000

*Significant difference.

significant difference in these values. For the dry season, there are no significant values in all the sampling points before and after the illegal dumping sites. The reason behind no statistical difference is that the increase after the dump sites was not too high. Even though there is no statistical difference, the increase in mean values after the dump sites is small as it is giving us an idea that these dump sites play a role in polluting the water, and if they remain unchecked, they will cause more pollution, making it hard for aquatic species to live.

For DO of the water in the wet season, it is only in Norwood that we reject the null hypothesis (H_0) and accept the alternative hypothesis (H_1) as there is a statistically significant difference in its values before and after the illegal dumping site. This implies that in this area, the decrease in DO was great, in fact, this is the only area that showed a decrease in DO for the wet season. In all other sites, we accept the null hypothesis (H_0) as there is no significant difference in the DO values before and after their illegal dumping sites. For dry season's DO, a significant difference can be seen in the sampling site before the Norwood illegal dumping site and the sampling site after. This means that we accept the alternative hypothesis (H_1) and reject the null hypothesis for this site. For all other sampling sites, there is no statistically significant difference.

For water's electrical conductivity, in all the sites we accept the null hypothesis (H_0) as there is no significant difference before and after all their dumping sites for both wet and dry seasons. For all parameters that showed no significant difference, it should be noted that, even if there is no statistical difference, that slight change in mean, means that there is an impact, and if the problem of illegal dumping along the river remains un-addressed, a built-up may occur, contributing more pollution to the river.

DISCUSSION

The sampling points before the illegal dump sites were used as the controlled environment in each site. This was based on the knowledge that water has the ability to replenish itself as it flows in a river (Yustiani *et al.* 2018). The decrease and increase in temperature are due to the local conditions of the sampling points, as they are not similar, some have shading while others do not (Bhateria & Jain 2016). In the Downtown sampling point after the illegal dump site, a noticeable decrease of 0.6°C in temperature can be noticed, and this is due to the water hyacinth that covers the water, and causes the sun to hardly reach the water (Ezama 2019). The high growth of this water hyacinth can be attributed to the nutrients coming from the waste disposed of in these illegal dump sites. Temperature of water is known to fluctuate over a river's length with latitude and elevation, but can also differ across short parts that are only a few meters away, depending on regional conditions (Selvanayagam & Abril 2015). For instance, a deep pool that is shaded is cooler than a shallow and sunlit one (Magaji & Oluyori 2021). An increase in temperature in Downtown may be attributed to the locality of the sampling point after, as it is open to the sun while the sampling point before is in the shadow of a water hyacinth.

With regards to water pH for the wet season, an increase in mean values for all sampling points after the dump sites can be seen except for the Polar Park (after) where a decrease in the mean value of water pH can be seen. Given that water replenishes itself as it flows (Liu *et al.* 2015), the possibility for this sampling point having a decreased pH, firstly, are characteristics of waste found in this dump site as they do not trigger water pH, secondly, water has cleansed itself at this point as it was high in the sampling point before, given rise to by the previous dump site. The slight increase in dry season's water pH is given rise by low rainfall when compared to the wet season. Rainfall is another driver of pollutants from dump sites to the water body.

The decrease of nitrite in the sampling point after Slovo Park is an indicator that waste in Polar Park did not have/had little nutrients and sewerage (Badiee *et al.* 2019). Besides waste from dump sites, some of the activities (such as farming and disposal of wastewater from treatment plants) occurring in these places also give rise to the pollution of water, and the illegal dump sites along this river add to that pollution. Between Polar Park dump site and the sampling point after, none of those activities are taking place. For the dry season, the decrease of nitrite after Norwood is the result of the decrease in rainfall, which is the main driver of the pollutants from the dump site to the river (van Emmerik *et al.* 2019). One of the factors that would have attributed to the decrease of nitrite was the decrease in waste generation in this area, as it is in the urban side of Mthatha, the country was from level 5 of COVID-19 lockdown during the collection of this data, so the businesses that produce much of the waste in this area were not well functioning.

For wet season's DO, the average mean showed an increase in sampling points after the illegal dump sites at Slovo Park, Polar Park, and Downtown. This increase was not expected, as it is known that when water is polluted, the DO decreases (Zhang *et al.* 2015). This also indicates that these dump sites do not produce much high waste, but if unchecked, they can have major impacts in the future on the water quality in terms of DO. The decrease in the DO was only noticed in the sampling point after the illegal dump site at Norwood. The decrease of DO in this dump site was expected as it occupies a large surface area and contains more waste in them. When waste enters the waterbody, it decreases the amount of DO available (Kamaruddin *et al.* 2017). For the dry season, all the sampling points after the illegal dump sites showed decreased average mean values in terms of DO except for the Polar Park sampling point. These were the expected results, and they revealed that the waste in these illegal dump sites enters the waterbody and decreases the available oxygen. The increase after the Polar Park was also expected as the dump site was cleared during the dry season. The decrease in oxygen after illegal dump sites was mostly expected in the wet season, but it was more evident in the dry season. This may be due to the wind that is available during the dry season, driving the waste to the water (Shang *et al.* 2016). Arguably, some organic compounds and phytoplankton can cause a decrease in DO, but in the case of this study, the sampling points were located before and after the illegal dump sites to control for such. The data were tested three times in each sampling point before and after the illegal dump site for validity.

Electrical conductivity in all the sampling points after the dump sites increased when compared to those before. It is said that electrical conductivity is an indicator of total salinity and total dissolved solids (TDS) (Gyamfi *et al.* 2012), then the findings of the wet season were expected, as the sampling points are after the dump sites for solid waste. These findings reveal that solid waste has entered and dissolved in the waterbody, therefore increasing its ability to conduct electricity (Meride & Ayenew 2016). For the dry season's electrical conductivity, the decrease after Slovo Park may be given rise to by the fact that it is in winter and there are fewer rainfalls to drive the solids waste to water, so the water cleaned itself as it was flowing from the sampling site before to the sampling point after. Also, the increase after the cleared dump site (Polar Park), may be given rise to the amount of soil that may have been driven by the wind to the water to increase TDS (Shang *et al.* 2016). When comparing the seasons, it is evident that the electrical conductivity was higher in the dry than in the wet season, suggesting that suspended solids were higher in the dry season in water than in the wet season.

In terms of *E. coli*, there was an increase in all sampling points after the dump sites for both wet and dry seasons. The increase in *E. coli* for the wet season was just too much and these are points where many soiled baby diapers were spotted, giving rise to these high values of *E. coli*. These dump sites are located closer to residential areas. Research reveals that there are a number of things that can affect the amount of *E. coli* bacteria in a river or stream, including the presence of both human and animal waste (pigs, goats, cows, dogs, and chickens) (Lubos & Japos 2013). For the dry season, there was still an increase in the amount of *E. coli* for all the sampling points after the illegal dump sites. The increase in the sampling point after Polar Park, even after the clearing of the dump site, is given rise to the activities practiced by the residents. During the dry season's data collection, the researcher noticed the residents disposing of their diapers exactly to the river just before one of the sampling points for this study, hence there is an increase in the levels of *E. coli*. As can be seen from Table 1, all other dump sites have diapers as the type of waste found in them, hence the increase in *E. coli* levels. Comparing the wet and dry season's findings, these were expected as there are high drivers of waste to the river in the wet season than in the dry season.

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings from this study, it is clear that illegal dump sites that are along the watercourses have a negative impact on the water quality. The negative impacts are more pronounced in wet seasons as the water from the rain drives the pollutants from dump sites to water. The impacts can also be noticed in the dry season, but they are higher in the wet season. Even if the deterioration caused by these dump sites is small, it matters because if the illegal dumping along the rivers remains unattended, it will have more negative impacts in the future. This will escalate to the problem of freshwater shortage, making it hard for humans to consume that water, causing more blockage to the flow of water, and also making it hard for aquatic species to thrive. It should not be avoided that water is a scarce resource, therefore it needs to be taken care of. An important linkage between river water quality and solid waste from illegal dump sites has been brought by this study, as some people improperly dispose wastes without knowing the impacts it will have on the surrounding environment.

This study concludes that water quality in the middle course of the Mthatha River has deteriorated as a result of solid waste that is improperly disposed there. Furthermore, its water is not suitable for human consumption and thus, there is a need to strengthen regulations against improper waste handling, especially in and along waterbodies. More frequent waste collection can play a huge role to prevent build-up and contamination of waterbodies. Environmental education on proper ways of disposing waste, and on the importance of keeping freshwater free from contamination, are also highly recommended as they can play a significant role in proper waste and water management in this area. The findings of this study bring local communities and policymakers to the awareness of the extent of harm caused by the dumping of waste on the water quality. This is necessary for influencing changes in behavior to interact with the environment. Additionally, the municipality's provision of extra skip bins would be very helpful in making some of these illegal dump sites into legal dump sites with tight guidelines mandating that waste only be disposed of within skip bins. Hiring local people to monitor adherence to the strict guidelines of waste dumping would also serve as a good measure to ensure compliance and would put an end to the problem of illegal dumping. A further study to understand the perceptions of people involved in the illegal dumping of solid waste is recommended so that more policies on waste dumping and water pollution can be formulated.

ACKNOWLEDGEMENTS

This study was supported by funding from the South African National Research Foundation (NRF) and the Department of Science and Innovation (DSI) through the Walter Sisulu University's Risk and Vulnerability Science Centre (RVSC) grant number UID75911.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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First received 27 August 2022; accepted in revised form 29 March 2023. Available online 11 April 2023