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The Impact of Sewage Water Overflow (SWO): An Analysis of Zandspruit River in Cosmo City, Johannesburg, South Africa

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Abstract: Cosmo City, situated in Johannesburg, Gauteng, has been experiencing sewage water overflows (SWO) for several years, and this raises concerns about the water quality of Zandspruit River. The study aimed to investigate the impacts of SWO on the Zandspruit River, and the perceptions of the community towards SWO. Water samples were collected from three sampling sites of Zandspruit River. Some water quality parameters were measured in the field using a multi-parameter water quality meter while other parameters were analyzed at a SANAS accredited laboratory. Results were compared with South African water quality guidelines and most water quality parameters were within permissible set standards. However, COD, *E. coli* and turbidity were above permissible set standards which indicates a highly polluted river. Furthermore, we assessed perceptions of the Cosmo City community towards SWO through questionnaires. The community ascribed the main causes of SWOs to population growth, blocked, and broken sewers. This study revealed that SWO around Cosmo City has a negative impact on the quality of river water and poses health risks. The combined evidence from both the experimental analysis and the community perception survey underscores the urgent need for effective management strategies to address the negative environmental and human health implications of SWO in the Zandspruit River. By integrating these findings and considering the broader implications of pollution on both the ecosystem and community well-being, policymakers and stakeholders can work towards implementing sustainable solutions to mitigate the risks associated with sewage water overflows

Key words: Cosmo city, sewage water overflow, *E coli*, water pollution, Zandspruit River.

Introduction

Water resource pollution has been the leading cause of water quality problems around the world (du Plessis, 2017; United Nations (UN), 2012). Moreover, the frequent release of sewage water overflows (SWOs) arising from current poor strategic wastewater management is also a long-standing problem in the water industry globally (Giakoumis & Voulvoulis, 2023). Therefore, SOW is a complex problem that poses human health risks and degrades the water environment (Weigner et al., 2021). Generally, sewage water overflows occur because of improper disposal of liquid and solid household waste, together with other resources such as agricultural and industrial runoffs (Salakinkop et al., 2014; Gqomfa et al., 2022). It contains pathogenic organisms and chemical features that can deteriorate the quality of water resources (Motheta, 2016), such as high concentrations of chemical oxygen demand (COD), biochemical oxygen demand (BOD), nitrogen (N),

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nitrate, (NO^{-3}) phosphorus (P), electrical conductivity (EC) and high ranges of pH (Sabeen et al., 2018).

Human and animal wastes have always been the main contributors of microbial pathogens in sewage water (Akpor et al., 2014) and microbial pathogens usually serve as water quality indicators (Akpor & Muchie, 2011). Recent contamination of water bodies by sewage or animal waste, viruses, protozoa and disease-causing bacteria is an indicative of the presence of *E. coli* (Wadzanai, 2010; Munyao, 2018).

During extreme weather events such as heavy rainfall, sewerage systems and pump stations become overloaded (Erskine et al., 2011). South Africa, like any other country in the world, is facing water quality problems, and most freshwater environments have been negatively affected by human activities and sewage water overflows (Department of Water Affairs and Forestry (DWAF), 1996; Council for Scientific and Industrial Research (CSIR), 2010; Naidoo, 2013). The Zandspruit River in Johannesburg, Gauteng has been experiencing SWO posing various health risks in the past. The release of SWO into Zandspruit River from the Cosmo City community has been the main cause of the water pollution since it flows into Watercombe Dam joins the Jukskei River which is interlinked with the Crocodile River that flows into the Hartbeespoort Dam to join the Limpopo River (Olumuyiwa, 2016; Van der Hoven et al., 2017) with no improvement over the past years. The health status of Zandspruit River is an environmental concern and warrants thorough investigations and there is no documented research work of water quality in the river.

The study area (Cosmo City) is generally characterised by a dense settlement and situated about 25 km North-West of Johannesburg Central Business District (CBD) (Figure 2). Cosmo City where low, middle, and high-income communities are integrated into one community sharing the same resources (Mphaka, 2015). The hydrologically sensitive areas in Cosmo City include wetlands and two perennial streams (Zandspruit and Pristine spruit) that run through the area (Mphaka, 2015).

Therefore, this research study aimed to investigate the impacts of sewage water overflowing into the Zandspruit River. That is, determining the concentrations of in-situ water quality parameters (temperature, pH, COD, EC and TDS) and other parameters such as nitrate, *E. coli* and various metals. The perceptions of Cosmo City communities towards SWO will be elucidated and the concentrations of the physicochemical parameters will be compared with the South African Water Quality guidelines for aquatic ecosystems and other set standards. The results will be provided in a seasonal comparison of the investigated parameters to discern seasonal variations in water quality.

Materials and Methods

We investigated the environmental implications of sewage water overflows on river water quality and the perceptions of the Cosmo City community. The data collection was divided into two methods: experimental and survey design methods, which were used as two major strategies to collect data for the current research study. Firstly, we used an experimental method to check the implications of sewage water on river water quality. Approximately 48 water samples were collected from three different locations of the stream (see Figure 1). In order to prevent contamination, the sample bottles were rinsed with EDTA prior to collection. Samples were collected on a seasonal basis (autumn, winter, spring, and summer) at each specific sampling location within a period of 12 months, and the sampling locations were chosen based on accessibility and safety.

The water sample was first collected upstream, away from sewage overflow; the second point was midstream, where sewage was flowing into the river; and the third point was downstream, where there was no sewage overflow (Table 1, Figure 1 and Figure 2). The samples were collected at 8:00 in the morning and transferred to the Aquatico Laboratories in iced coolers at 4°C to prevent a change in volume due to evaporation prior to analysis. The water samples were collected from a river during sewage water overflows, and the samples were sent to the laboratory for analysis of physico-chemical parameters. Finally, the water samples were compared to the set standards for water quality and their levels were determined.

Later, the samples were analysed in triplicate at Aquatico Laboratories accredited by the South African National Accreditation System (SANAS). The pH, temperature, electrical conductivity (EC), and total dissolved solids (TDS) were measured in the field using a multimeter reader (HANNA-HI 9829). The water was also tested for *E. coli*, chemical oxygen demand (COD), metal ions (copper, cadmium, zinc and lead), and non-metal ions (nitrates and phosphates) in an accredited laboratory.

Therefore, we went further to understand the impact of sewage water in the river, then we explored the perceptions of the Cosmo City community on sewage water overflow. The survey method was employed to

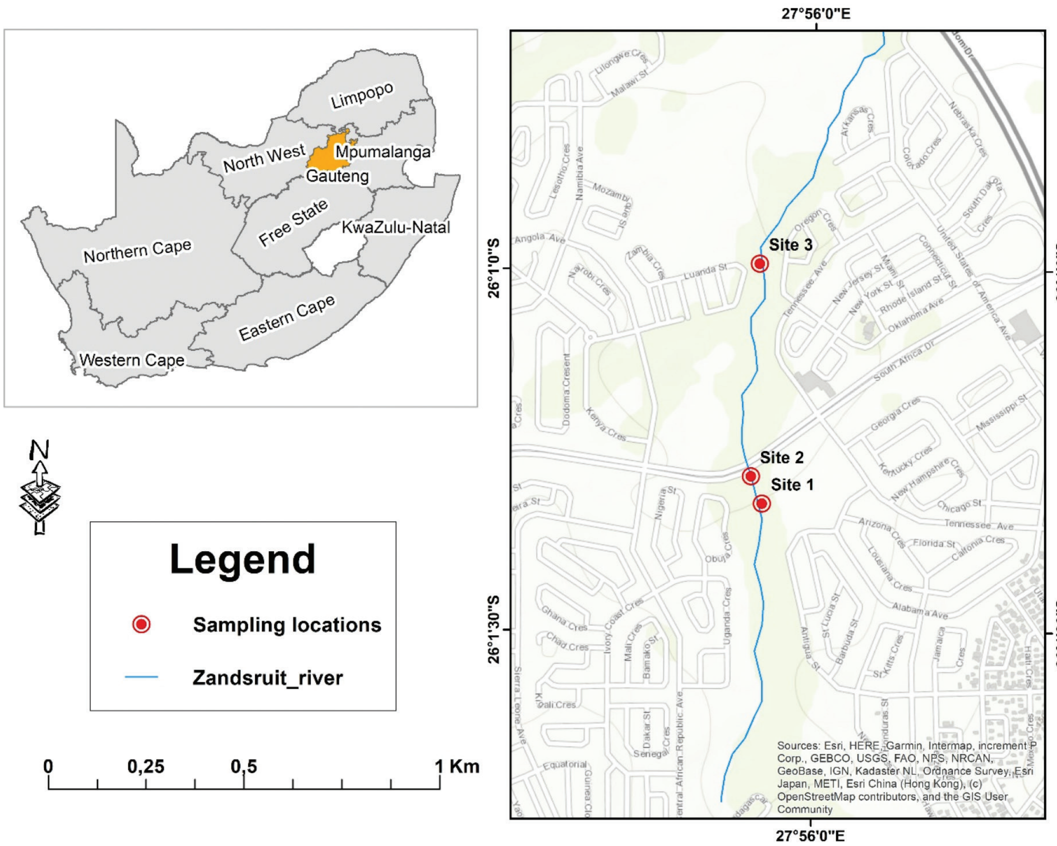

Figure 1: The map indicating the study area, the sampling locations (Site 1, Site 2, Site 3) from the river and the study area in a context of Gauteng Province in South Africa.

Figure 2: The pictures indicate a sewage overflow at the Cosmo City area and sample collections at the Zandspruit River. (A) Sewage runoff. (B) Water sample collection at the river. (C) Sewage runoff in the street. (D) sewage water from the drain. (E) The waterflow at the river.

Table 1: Coordinates of the selected water sampling points and the respective locations at the river

Site	*Location*	*Coordinates: X & Y*	
Site 1	Zandspruit: Upstream	27.932002	-26.022047
Site 2	Zandspruit: Midstream	27.931715	-26.021421
Site 3	Zandspruit: Downstream	27.931906	-26.016514

understand the anthropogenic impact and effects of sewage water. A population of about 250 households was chosen randomly based on availability. The purpose of the questionnaire was to assess the community's perceptions, attitudes and knowledge towards sewage water overflow and its impacts (Supplementary 1). Access to the community was arranged with the assistance of the ward councilor. Questionnaires comprised of closed-ended questions were (Mnisi, 2011) administered in English and translated for the community. The survey was conducted over a period of 3 months and random numbers were generated using Excel 2016. The data collected through questionnaires were analysed using IBM SPSS statistics 28.0.1.0.

Results and Discussion

Physico-Chemical Parameters

The pH was dependent on the interactions of substances dissolved in water, such as aquatic plants, photosynthetic process, respiration of aquatic living organisms, precipitation and decomposition of organic matter (Saad et al., 2017). The highest pH value of 8.08 was detected during autumn (Figure 4a) and the lowest pH 7.74 value during summer (Figure 3a). Usually, the dilution of river water due to sewage and precipitation increases the pH value of water (Yee et al., 2016). The average mean pH value detected was 7.838 and falls within the standard limits of 5.5 – 9.5 set by DWAF (1999); Levi and Co (2007); Domestic Water Sanitation (DWS) (2017).

Factors such as seasonal variations, exposure to solar radiation and cloud cover usually influence the changes in temperature (Otieno et al., 2017). In this study, the highest temperature value of 22.27°C was observed during the summer season and the lowest value of 20.27 °C was recorded during the winter season (Figure 3b). The temperature values of the results corresponded with the recommended water quality standards of 25-35°C, 30°C and 37°C set by DWAF (1999), EU (EPAI, 2001), Levi & Co (2007).

Electrical conductivity (EC) is dependent on the nature and migration of the ionic species in a solution, and it increases with the level of ion mobility in the water (Mohammed, 2017). EC values in this research ranged from 37,9 to 73,9 mS/m, with the highest value of 73.9 mS/m detected during autumn, and the lowest value of 37,9 mS/m during summer (Figure 3c). Therefore, the EC value dropped from the permissible limits of 70 – 150 mS/m set by (DWAF 1999); (DWS 2017). Similarly, TDS values in surface water were higher in winter and lower in the summer as described in Gadhia et al. (2012). The highest value of TDS (480.35 mg/L) was recorded during autumn and the lowest value (246.35 mg/L) during summer (Figure 3d). During summer, the lowest value of TDS (246.35 mg/L) was detected which may be because of rain and the high mixing of water from SWO or storm water. The TDS values were lower than the standard limits of 500–1500 mg/L for wastewater in South Africa (Van Schoor, 2005; UP & SALII, 2013).

However, the phosphate concentration ranged from 0.667 to 1.86 mg/L, with the highest value of 1.86 mg/L detected in autumn, and the lowest value of 0.667 mg/L detected in summer (Figure 3e). The high phosphate concentration in autumn might be because of detergent formulations released into domestic wastewater, while the lower value in summer might be due to rain in summer (rainy season). The standard limits set by the DWAF (1999), and the DSW (2017) for the discharge of wastewater is 1-2.5 mg/L, which is higher than the phosphate levels obtained. However, EPAI (2001) set standard limits of 0.02–0.07 mg/L that correlates with our results and the phosphate levels in the water pose no danger to the river water quality.

Nitrate concentration is usually attributed to an increase in fertilisation processes from agricultural practices and sewage nearby (Motheta, 2016; Georgieva et al., 2018). In this research, nitrate concentrations ranged from the lowest (0.394 mg/L) in spring to the highest (2.52 mg/L) in autumn (Figure 3f). However, the lower concentration of nitrates in spring could be attributed to the dilution of sewage water in the river due to rain. The average concentration of nitrates for all four seasons was 1,354 mg/L (Figure 4f). These concentration levels were below the South African standard set by DWAF (1999), EPAI (2001), Gadhia et al. (2012), DWS (2017). These parameters do not pose a potential threat to the water environment.

The identical concentrations of 0.002 mg/L for Cu, Zn and Cd during four seasons were observed (Figure 4a). However, the Pb value remained constant at 0.004

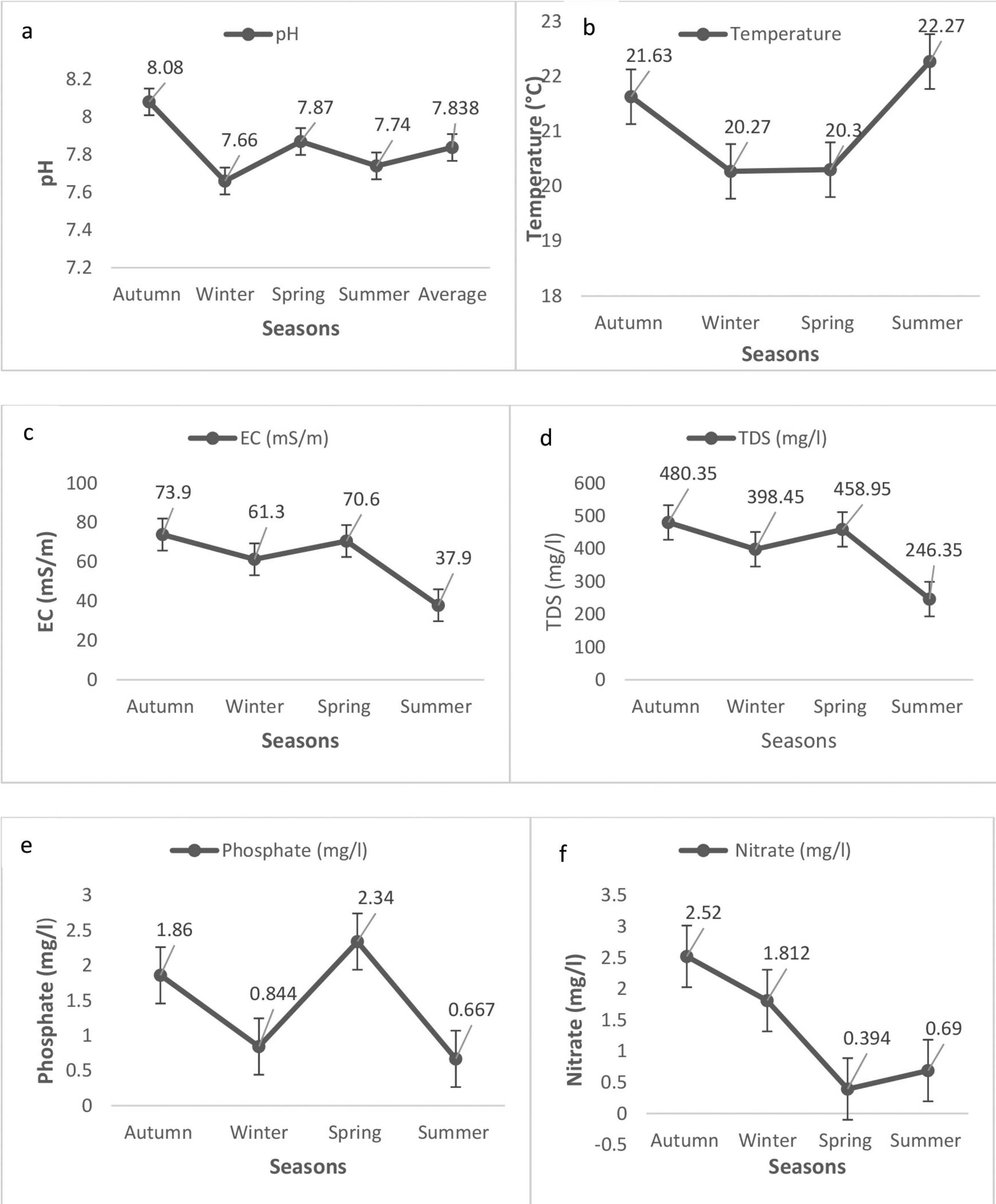

Figure 3: The laboratory analysis results of physico-chemical parameters. The results indicate seasonal water parameters of (a) pH, (b) temperature, (c) EC, (d) TDS, (e) phosphates, (f) nitrates.

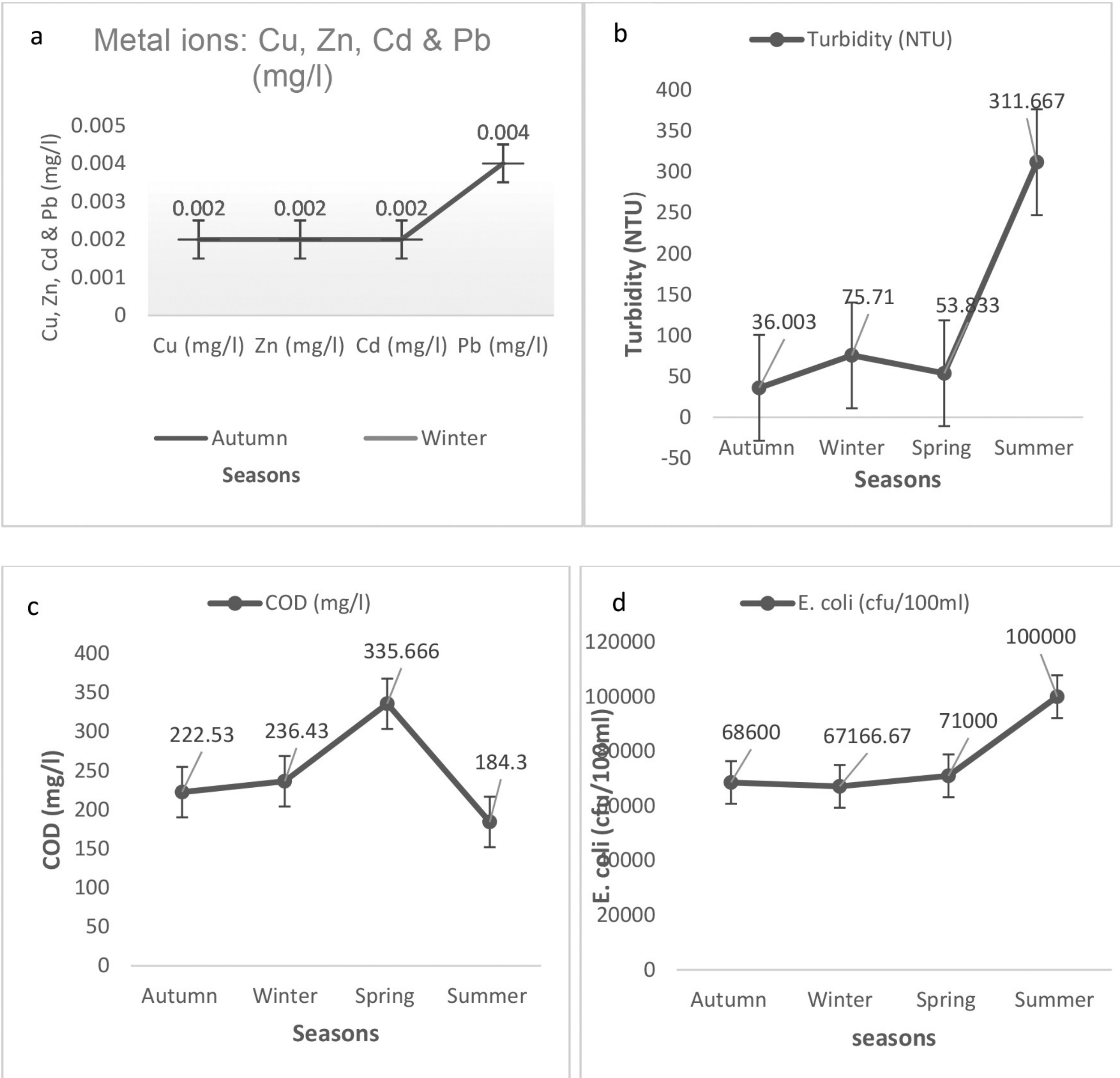

Figure 4: The results indicate seasonal average mean values of (a) Metal ions, (b) Turbidity, (c) COD, and (d) E. coli.

mg/L in all four seasons (Figure 4a). The concentration of Cu, Zn, Pb and Cd were lower than the standard limit of 0.01 mg/L set by the DWA (1999), EPAI (2001), Levi and Co. (2007) for wastewater. Therefore, the parameters of Cu, Zn, Cd and Pb concentrations corresponded to the standard limits of DWAF (1999), Levi & Co. (2007). The concentration of metal ions found to be constant might imply that minimum metals were discovered in the river because of sewage water overflow. Even though metal ions are released into the river, they settle down and become undetectable in the river water. Although the concentrations of heavy metals were detected in lower limits, they could still pose a threat to living organisms (Akpor et al., 2014) since they accumulate in food chains (Kaushal & Singh, 2017).

Our results indicated turbidity mean value ranging from 36,003 to 311,667 NTU, with the lowest value (36,003 NTU) detected in autumn and the highest value (311,667 NTU) in summer (Figure 4b). The average mean value for turbidity was 119,303 NTU for all four seasons which is above the standard limits of 10 NTU (Gadhia et al., 2012). The turbidity value indicates a threat to the aquatic living organisms. The Zandspruit River's flow rate was low during sample collections with the lowest value of turbidity in autumn which could be because of no rainfall that caused flooding and the re-suspension of deposited sediments. The COD values ranged from 184.3 to 335.67 mg/L, with the highest value of 335.67 mg/L detected in the spring season and the lowest value of 184.3 mg/L detected in the summer season (Figure 4c). The average value of COD was observed as 244.73 mg/L in all four seasons, which was found to be higher than the permissible limits (DWAF,1999; EPAI, 2001; DWS, 2017). High values of turbidity and COD can be because of organic matter from sewage, runoffs and water treatment. As a result, the COD concentrations detected in this study might pose a threat to the aquatic environment.

The concentration of *E. coli* according to the results ranged from 68600 to 100000 cfu/100 ml. The lowest concentration of *E. coli* (68600 cfu/100 ml) was detected in autumn and the highest concentration (100000 cfu/100 ml) in summer. The average mean concentration observed was 244.732 cfu/ml (Figure 4d). These concentrations were found to be higher than South African and European standard limits of 1000 cfu/100 ml as described by the EPAI (2001) and the DWS (2017). Naidoo & Olaniran (2014) demonstrated that the concentration of *E. coli* should be zero cfu/100ml in the water. Thus, the concentration of *E. coli* detected might pose a danger to the environment and the quality of river water.

Questionnaire Survey

After analysis of the sewage water in the laboratory, a questionnaire survey was drafted to understand the general perceptions of the Cosmo City community towards SWO. A total of 250 participants responded to the questionnaire and many respondents were married males with household members of about 3-6 in numbers (Supplementary 2). The findings of the survey on the causes of sewage overflow revealed that most respondents have the perception that population growth is the major cause of SWO (Supplementary 3).

The results pertaining to the perceptions of the community towards sources of sewage water revealed that domestic, industrial, agricultural, and commercial uses were the main causes of SWO (Supplementary 3). Similarly, Borisova et al. (2013) stated that industrial and agricultural uses and runoffs from homes were the biggest contributors of SWO that pollute streams, rivers, and lakes in urban areas.

It was discovered that sewage water overflow has been part of the life of the community of Cosmo City for more than five years (Supplementary 3). Most respondents indicated that SWO has a detrimental impact on their environment (Supplementary 4). Mbonambi (2016) and Gqomfa et al. (2022) revealed that SWO affected the environment negatively and posed a high risk to the health of the residents.

There are various management techniques people can use when they encounter SWO in their area (Tafuri & Field, 2010) and most respondents indicated that a good way of managing SWO was to contact the local municipality or a licenced plumber (Supplementary 5). Generally, the results showed that people in Cosmo City request the municipality for assistance to eradicate SWO.

Also, the respondents had perceptions that the sewerage system's capacity was too small, deteriorating and needed to be upgraded or should be subjected to routine inspections. Many respondents said that the introduction of an education campaign in the community and routine inspections of the sewer infrastructure would be the best way to manage SWO in the community. Education campaigns were recommended by the respondents as the best strategies to provide knowledge and information about water quality issues in a specific community in the past (Eck et al., 2019).

The integration of the community perception survey with water quality analysis was essential to bridge the gap between qualitative insights from the survey and quantitative data from water quality analysis. Therefore, by combining these two approaches, a more comprehensive understanding of the issue of sewage water overflows in the Zandspruit River was elucidated.

Conclusions

Most water quality parameters were found to be within the permissible standard limits with COD, *E. coli* and turbidity parameters being above the permissible set standards which is an indicative of a highly polluted Zandspruit River. These findings highlighted the severity of water quality degradation in the river due to SWO, with implications extending beyond environmental concerns to pose significant health risks to the community.

Therefore, the survey results were found to be corresponding with the experimental results. The combined evidence from both the experimental analysis and the community perception survey underscores the urgent need for effective management strategies to address the negative environmental and human health implications of SWO in the Zandspruit River. By integrating these findings and considering the broader implications of pollution on both the ecosystem and community well-being, policymakers and stakeholders can work towards implementing sustainable solutions to mitigate the risks associated with sewage water overflows. Strategies such as education campaigns, upgrading and routine maintenance and inspections of sewer infrastructure should be implemented to mitigate the issues of SWO in Cosmo City. Measures should be put in place to reduce the levels of water contamination from sewage overflows. Therefore, this research will help Johannesburg Water and the Department of Water and Sanitation to manage and take appropriate actions against the prolonged sewage water overflows in Cosmo City.

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Additional Information

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