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ORIGINAL PAPER

Physicochemical properties of wastewater effluent from two selected wastewater treatment plants (Cape Town) for water quality improvement

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Abstract
Effluent from wastewater treatment plants (WWTPs) is one of the main sources of pollution that seriously affect the physicochemical parameters in water bodies. This occurs particularly when partially treated or untreated effluent is released to various aquatic ecosystems. This constitutes a potential danger to the general environment. To safeguard the lives of human, aquatic and other living organisms, regular monitoring of wastewater effluent to ascertain their compliance with both national and international regulatory limits for water quality improvement is very crucial. This research work was carried out using standard methods to evaluate ten physicochemical parameters from the effluent of two WWTPs in Cape Town, South Africa. Our findings were: temperatures (16.90–25.33 °C), pH (5.85–7.85), EC (923.00–1294.17 µS/cm), TDS (590.72–828.27 mg/L), DO (1.30–5.50 mg/L), SO_4^{2-} (3.23–163.18 mg/L), COD (23.70–898.58 mg/L), BOD (9.17–252.44 mg/L), Cl^- (48.17–378.48 mg/L) and PO_4^{3-} (0.10–11.32 mg/L). Temperature, pH and SO_4^{2-} levels in the two WWTPs were within the recommended limit for wastewater discharge by the Department of Water Affairs and Forestry (DWAF), South Africa and the United State Environmental Protection Agency (USEPA). However, other parameters did not comply fully with both DWAF and USEPA standards. The result showed that effluents from these WWTPs are possible sources of pollution to the receiving water bodies and calls for enhancement of the WWTPs operations to ensure safe effluent discharge.

Keywords Physicochemical analysis · Wastewater treatment plants · Wastewater effluent · Permissible limit

Introduction

Human activities are not static, and the contaminations of the environment (water, air and soil) globally are the results of increased population and various anthropogenic activities such as agriculture, industrialization, urbanization, change in the pattern of life and climate change (Olujimi et al. 2012; Ullah et al. 2018). Majority of the results or products of these contamination go to the wastewater treatment plants (WWTPs) and consequently have a great impact on the physicochemical properties of wastewater (Paltahe et al. 2018). Wastewater treatment plants (WWTPs) have therefore been identified as one of the main sources of variation in the physicochemical parameters of the aquatic ecosystem due to the discharge of partially treated effluent containing different hazardous materials into the receiving water bodies (Fatta-Kassinos et al. 2011; Paltahe et al. 2018).

Wastewater is generated via different sources including homes, industries, farmland and other usage points (Koopaei and Abdollahi 2017). Therefore, it encompasses various organic and inorganic compounds as well as pathogenic microorganisms (Lokhande et al. 2011; Rana et al. 2017). These constitute potential dangers to the natural water system and hence becomes hazardous to life (Lokhande et al. 2011; Koopaei and Abdollahi 2017). The continuous pollution of the aquatic environment with wastewater has a detrimental impact on health and the environment (Lokhande et al. 2011; Rana et al. 2017; Koopaei and Abdollahi 2017).

The challenge of water scarcity arising as a result of reduction in the quantity and quality of freshwater resources available to man as well as the ecosystems is a global phenomenon (Abbott et al. 2019). Globally, 2.1 billion people

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lack access to clean water and about 4.5 billion have no access to adequate sanitation (Hokkanen et al. 2018). Shortage of freshwater has been a great problem in many African countries including South Africa, as well as some developed countries (Aniyikaiye et al. 2019; Abbott et al. 2019; Robin 2019). Recent prediction by the UN indicates that two-thirds of the world population would experience water scarcity by 2025 if immediate intervention is not provided (Aniyikaiye et al. 2019).

On the other hand, the use of treated wastewater effluents seem to be the only water resource that is increasing as other sources such as dam, rivers and lakes are decreasing (Zabir et al. 2016). In the recent past decades, the use of wastewater effluent has gained immense popularity due to some factors such as climate change, food insecurity and industrialization (Patil et al. 2012). On the contrary, the major part of these wastewater effluents is employed for agricultural purposes which could lead to the accumulation of toxic substances from wastewater in plants (Zabir et al. 2016; Koopaei and Abdollahi 2017). South Africa as a semiarid region with a level of water inadequacy has been exploring wastewater reuse especially in landscaping, agriculture and industrial application (Adewumi et al. 2010). This has to be monitored and regulated to prevent any detrimental effect on human health and the environment (Koopaei and Abdollahi 2017).

Water is essential to life, and the demand for wastewater could increase drastically in Cape Town, South Africa. This is so because the city recently experienced a drought and water crisis in 2018 tagged 'Day Zero' that threatened a total collapse of the water and sanitation system (Robin 2019). Therefore, to reduce water pollution and ensure a safe environment for all, periodic and regular monitoring of the physicochemical qualities of wastewater effluent is crucial (Chigor et al. 2013; Aniyikaiye et al. 2019). This will ascertain their quality and compliance with the relevant regulatory bodies.

United State Environmental Protection Agency (USEPA) is an international environmental regulatory body founded in 1970 through the enactment of the Clean Water Act (CWA) by American Congress in 1972. The objective of the CWA is the restoration and maintenance of chemical, physical and biological integrity of water. USEPA implements the environmental law made by the American Congress to ensure environmental protection. USEPA made regulations, sets national standards and enforce them to ensure clean air, water and land (Blomain 2020).

In South Africa, the Department of Water Affairs and Forestry (DWAF) is the regulatory body for South Africa's water and forestry resources. The body has the mandate to formulate and implement policies governing these two sectors. It sets the limit for wastewater discharge to ensure access to clean water and good hygiene (DWAF 2010; Sun and Dong 2016; Wood et al. 2016). The objective of this work is, therefore, to evaluate the physicochemical properties of wastewater effluents from the two selected WWTPs in Cape Town, South Africa and compare their levels to both the national (DWAF) and international (USEPA) regulatory values. The results obtained will be useful in ensuring safe water that meets standards for use in agricultural, industrial and other applications that would depend on wastewater effluent, hence a healthy environment.

Materials and Methods

Description of WWTPs

The two WWTPs are located in Cape Town in Western Cape in South Africa. The first plant is identified as WWTP 1 and the second one is WWTP 2, respectively, as shown in Fig. 1.

The total capacity of WWTP 1 is 70 Mega litres (ML). It received influent from domestic and industrial run-off water. Raw influent passes through coarse and fine screening, respectively, for the removal of solid particles. It then undergoes anaerobic and aerobic digestion with activated sludge and moving bed bioreactors (MBBR) digestion for organics removal (by converting organic matter into methane and carbon dioxide), nitrification, denitrification and detoxification. Chlorination is used for disinfection. Lastly, the plant passes the final effluent through UV radiation as the tertiary treatment before its discharge (Olujimi et al. 2012; Veolia 2017).

The total capacity of WWTP 2 is 40 ML and the influent came mainly from domestic and agricultural wastes. The plant uses the same treatment process as that of WWTP 1 except for the tertiary treatment that uses UV radiation (Veolia 2017).

Sample collection

Sample collection was carried out according to the standard methods described by USEPA (2009) and Prasse et al. (2010). Final treated wastewater effluents were collected every month from April 2018 to April 2019 (except January 2019 for a logistic reason). This was done to have samples covering the four seasons of the year in Cape Town and to provide data/information on likely seasonal variation of the physicochemical parameters within the sampling period. The specific dates of samples collection are as shown in Table 1. Grab wastewater samples were collected at both plants. In WWTP 1, the final effluent was collected at the discharge point after UV treatment sampling point while the final effluent was collected at the discharge point after chlorination at WWTP 2. Designated plastic fetcher attached to a rope was used to take samples into the prepared sample containers (prewashed

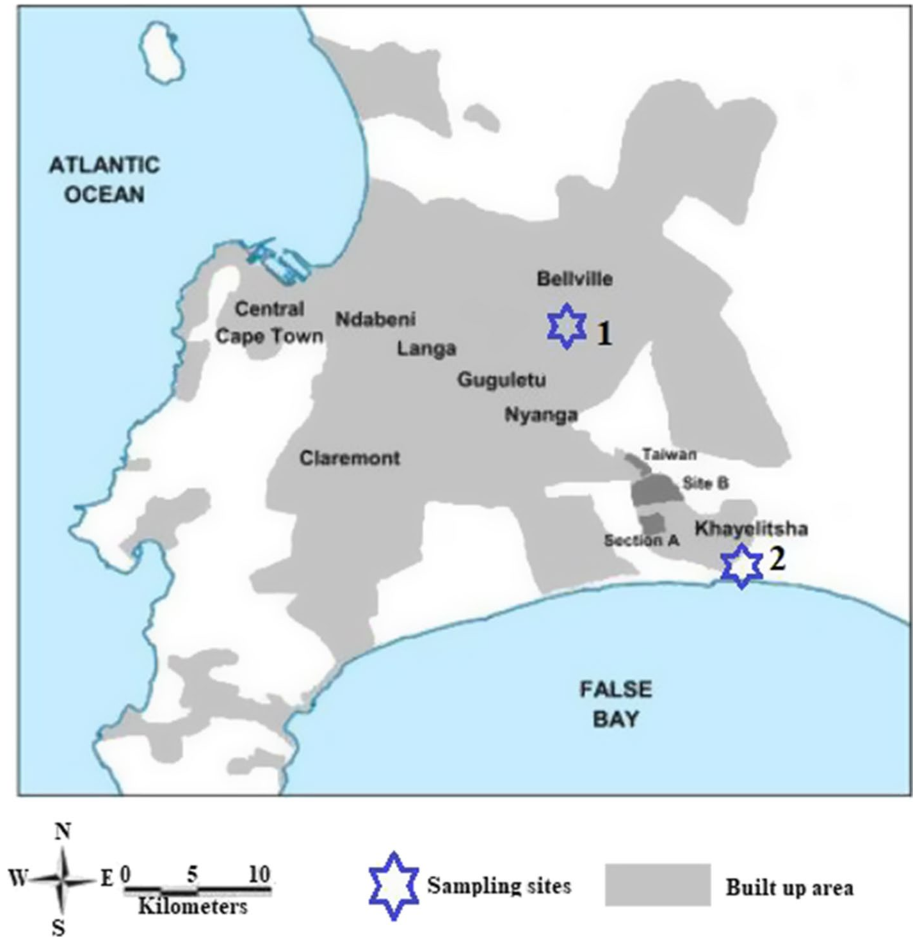

Fig. 1 Description of sampling location

2.5 mL Winchester bottle). At every sampling point, both the fetcher and sample bottles were rinsed thrice with the intended wastewater sample before sample collection. Duplicate samples filled to the brim of the sample containers were collected every month in each plant. A total of twenty-four samples were collected from each WWTP within the sampling period.

Experimental method

Physicochemical parameters, temperature, pH, electrical conductivity (EC) and dissolved oxygen (DO) were measured with a Hanna multi-parameter probe HI 9828 after calibration according to the manufacturer manual. Chemical oxygen demand (COD) was determined with an open reflux colourimetric method using USEPA approved method for 20–1500 mg/L range (USEPA 1980). Cl^-, SO_4^{2-} and PO_4^{3-} were performed (Mesquita et al. 2002; Mussa et al. 2009; Pradhan and Pokhrel 2013), respectively. BOD_5 was performed by (Patnaik 2017) and TDS was calculated by multiplying EC with 0.64 (Rusydi 2018). All determinations were performed in triplicate.

Statistical analysis

The data obtained from the wastewater samples were analyzed by graph pad prism software. For significant F value, the least significance difference (LSD) was used for mean comparison at 5% level. Statistical analysis was used to indicate significant differences ($P < 0.05$). The difference is detected as greatly significant when the P value is lower than 0.001, statistically significant if P value is lower than 0.05 and non-significant if the P value is greater than 0.05.

Results and discussion

The result obtained was compared with the permissible limits from the Department of Water Affairs and Forestry (DWAF), South Africa and the United State Environmental Protection Agency (USEPA).

Monthly variation of temperature in WWTPs 1 and 2

Figure 2 presents the monthly variation of temperature in WWTPs 1 and 2. The temperature ranged between 16.9 and 25.3 °C in both plants. The temperatures recorded in the two plants were lower compared to the values (19.0–36.0 ºC) reported by Agoro and his co-workers for wastewater effluents (Agoro et al. 2018). All the temperature range in the two plants complied with the regulation limits for discharged effluent into water bodies by DWAF and USEPA as shown in Table 2. The lowest temperature (16.9 °C) was obtained from WWTP 2 while the highest temperature (25.3 °C) was obtained in plant 1. The difference in temperature range observed between the two WWTPs might have occurred because plant 1 received a lot of industrial effluent in addition to the domestic effluent while plant 2 received mainly domestic and agricultural effluent. This is so because industrial effluent generated from cooling processes has been reported as one of the major sources of thermal pollution resulting in high temperature (Lokhande et al. 2011).

The lowest temperature was recorded in July 2018 which happened to be the peak of winter in the southern hemisphere where the pilot study was conducted. The highest temperature value (25.3 °C) was recorded in March 2019, the peak of Autumn in the study area. As observed within

Table 1 Dates of sample collection

WWTP 1	WWTP 2
9/ 4/2018	10/ 4/2018
10/5/2018	10/5/2018
17/6/2018	17/6/2018
31/7/2018	22/7/2018
18/8/2018	18/8/2018
15/9/2018	15/9/2018
26/10/2018	21/10/2018
13/11/2018	11/11/2018
6/12/2018	2/12/2018
13/2/2019	13/2/2019
26/3/2019	24/3/2019
21/4/2019	21/4/2019

Table 2 Regulatory guidelines by DWAF and USEPA

Parameters	Units	DWAF	USEPA
T	°C	35	Below 35
pH	–	5.5–9.5	6.5–8.5
EC	(µS/cm)	750	2500
TDS	(mg/L)	450	500
DO	(mg/L)	7.5	6.0–9.5
$SO4^{2-}$	(mg/L)	200	250
COD	(mg/L)	75	Below 1000
BOD	(mg/L)	3.0–6.0	Below 500
Cl^{-}	(mg/L)	100	250
$PO4^{3-}$	(mg/L)	10	4

*Department of Water Affairs and Forestry (DWAF), South Africa

**United State Environmental Protection Agency; Drinking Water Regulations and Health Advisories, EPA 822-R-94–001, May 1994

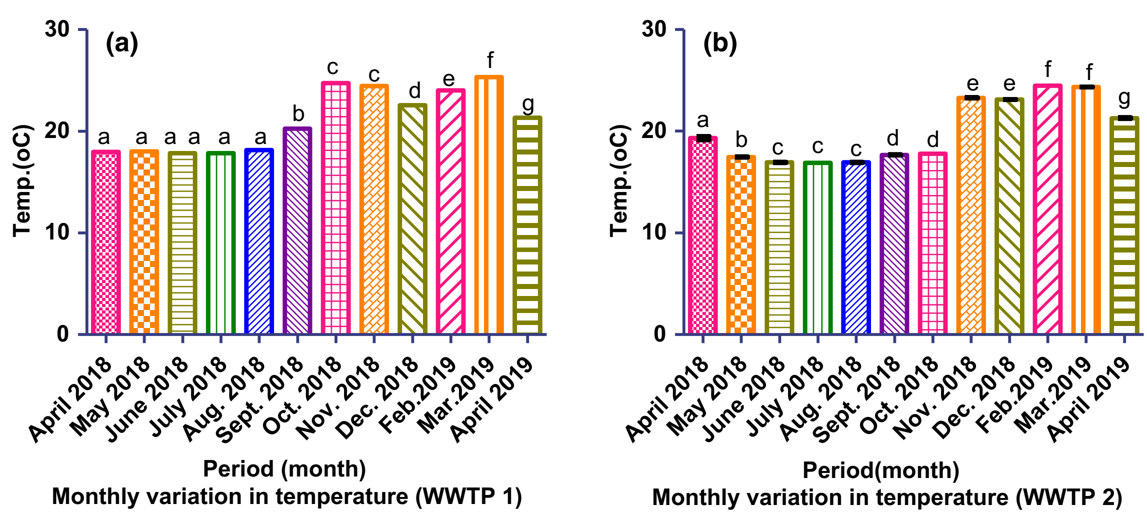

Fig. 2 Monthly variation of temperature in WWTPs 1 and 2

the first 5 months (April-August 2018) of samples collection, the temperatures obtained in both plants except April and May in WWTP 2 are lower and fairly stable. They did not show any significant difference ($P > 0.05$). From September however, the temperature in the two plants started rising and peak in February/March 2019. The temperature variation might have resulted mainly due to prevailing environmental factors viz a viz, climate change and seasonal variation in Cape region, South Africa. The result observed in both WWTPs conforms with the findings for temperature variation of dairy wastewater (Tikariha and Sahu 2014). They recorded a lower temperature during the winter while a higher temperature was reported during the summer months (Tikariha and Sahu 2014). A similar observation of temperature variation of 18.1 and 28.5 °C was observed in the three different sampling periods which was also attributed to seasonal variations (Iram et al. 2013).

Monthly variation of pH in WWTPs 1 and 2

The result of the monthly variation of pH within the sampling period (April 2018-April 2019) in WWTP 1 and 2 is presented in Fig. 3. The pH for the two treatment plants varied between 5.85 in August 2018 and 7.85 in February 2019 and they occurred in WWTP 2. The pH range (5.85–7.85) recorded in WWTP 1 study shows a similar trend of observation to the pH range (6.1–7.7) reported elsewhere for wastewater effluent from a dairy farm (Tikariha and Sahu 2014). Most of the pH values recorded within the sampling period in WWTP 1 are around neutral (pH 7), but they are significantly different from one another. In WWTP 2 however, the pH values recorded in the majority of the months in WWTP 2 are fairly stable around pH 7.5 except August (5.85) and October (6.56) which were significantly different from one another and the rest of the months. The result obtained shows proximity to the pH values (7.22, 7.78) as reported by Shrestha et al. (Shrestha et al. 2017). The stability observed for these results could be because there was a steadiness in the pattern of the domestic influent discharge received by the plant. However, the stable pH values tending toward alkalinity could be as a result of a high level of carbonate use in the treatment method. This was evident because the sample always produces foam during sampling. A similar observation was reported elsewhere, and in their study, they reported that high level of pH and organic matter content could render the majority of trace elements immobilized which invariably could lead to an increase in pH value (Iram et al. 2013). The pH range in the two plants complies with the permissible limit for wastewater discharge effluent to water bodies by both DWAF and USEPA as in Table 2.

Monthly variation of EC in WWTPs 1 and 2

Results of monthly variation of EC in WWTPs 1 and 2 between April 2018 and April 2019 are presented in Fig. 4. The EC in WWTP 1 varied between 923.00 in April 2019 and 1294.17 µS/cm in October 2018, respectively. The lowest (923.00 µS/cm) and highest (1294.17 µS/cm) EC values occurred in WWTP 1 and WWTP 2, respectively. The lowest EC value (923.33 µS/cm) in April 2019 varies significantly ($P < 0.05$), from all other ECs values obtained during the sampling months and it occurred in Autumn. Likewise, the highest EC value was recorded in October which was the Summer period. This points to the fact that

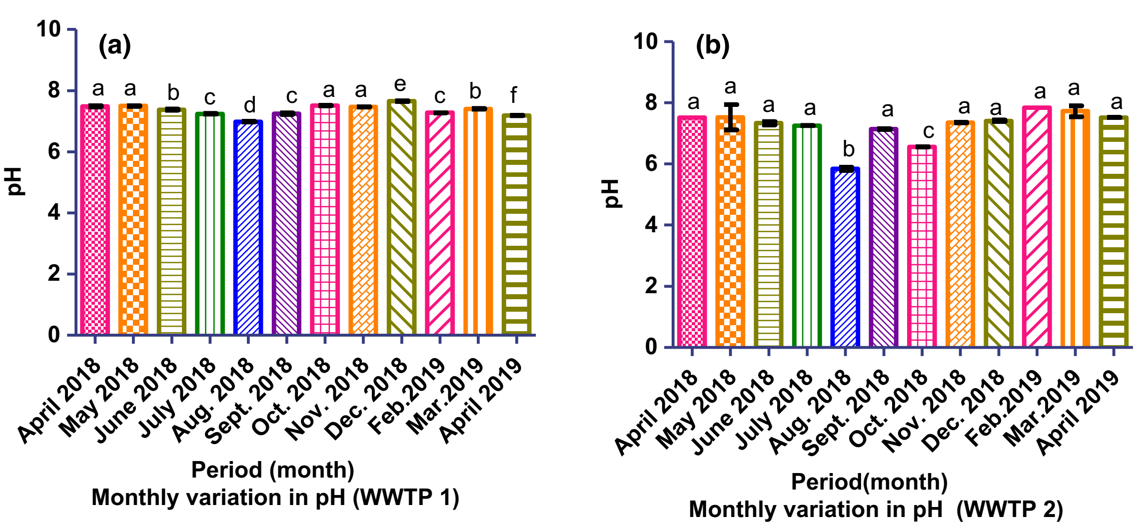

Fig. 3 Monthly variation of pH in WWTPs 1 and 2

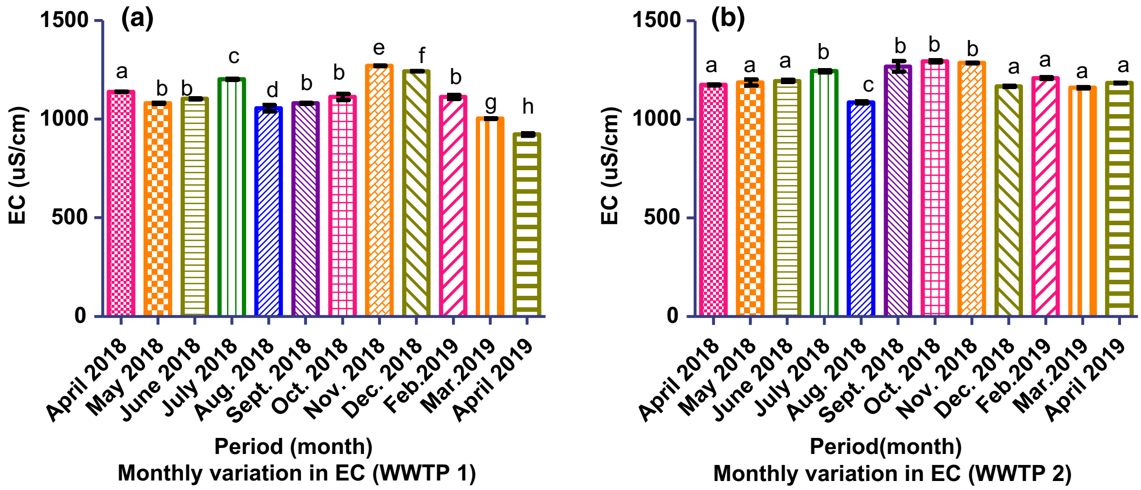

Fig. 4 Monthly variation of EC in WWTPs 1 and 2

seasonal variation could affect EC value. This was evident in August 2018 when the EC value lowered to 1055.50 µS/cm which could be the result of very cold weather in winter. However, a steady and gradual increase in EC sets in from September in both WWTPs which marks the beginning of spring and continues through the summer period. In both WWTPs, (except July 2018) lower values of EC experienced during winter/autumn and higher EC values recorded in the spring/summer could be as a result of variation in temperature within the sampling period. This observed trend is in agreement with the report from another research work that electrical conductivity is usually higher in the summer and decreases in the winter because temperature variation affects electrical conductivity (Kriegel and Palmour III 2012). This trend was also observed at Parkside sampling site area during the winter period in the determination of physicochemical variation of Buffalo River estuary, in Eastern Cape Province of South Africa (Chigor et al. 2013).

The range of EC in WWTP 2 (1085.67–1294.17 µS/cm) was observed to be a little higher than that observed in WWTP 1 (923.00–1270.33 µS/cm). This could be the effect of the higher altitude in WWTP 1 compared to WWTP 2. A similar result was reported by Oyem and his group that lower ECs (8.23–14.46 µS/cm) and (8.24–8.25 µS/cm) were recorded in Owa Alero and Alihame in Nigeria, respectively, with lower altitude whereas an average of 12.22 µS/cm and 12.23 µS/cm was reported, respectively, for Agbor and Owa that have higher altitude (Oyem et al. 2014). The relationship

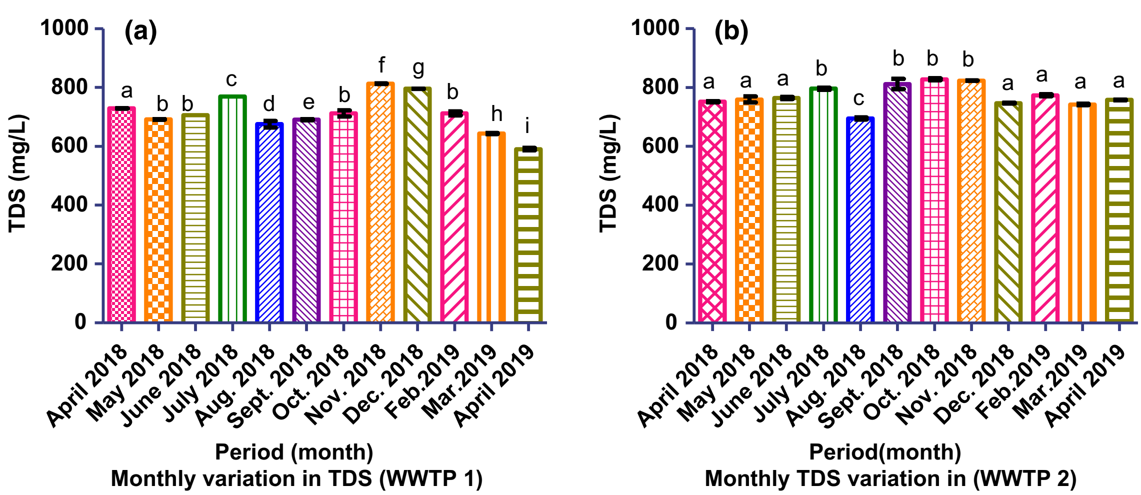

Fig. 5 Monthly variation of TDS in WWTPs 1 and 2

between EC and altitude could be attributed to the effect that WWTP 1 with higher altitude could have a lower water table and hence experience higher net leaching effect than WWTP 2 (Oyem et al. 2014). The EC values in both plants did not comply with DWAF standard (750 µS/cm) limit but they all comply with USEPA discharge limit of 2500 µS/cm Table 2.

Monthly variation of TDS in WWTPs 1 and 2

Figure 5 presents the monthly variation of TDS recorded for wastewater effluent from WWTP 1 and 2. The TDS values in both WWTPs ranged between 590.72 in April 2019 and 828.27 mg/L in October 2018, respectively. The lowest and highest concentrations were obtained from WWTP 1 and WWTP 2, respectively. All the TDS values in both WWTPs are higher than the recommended standards for wastewater discharge by both DWAF(450 mg/L) and 500 mg/L by USEPA. The result within the sampling period shows varying significant differences ($P < 0.05$). The lowest TDS value in WWTP 1 (590.72 mg/L) in April 2019 and the lowest value in WWTP 2 (694.83 mg/L) in August 2018 are significantly different ($P < 0.05$) from the TDS concentration in all the other sampling periods. The highest concentration (813.01 mg/L) in WWTP 1 differs significantly ($P < 0.05$) from all other TDS values. The highest TDS (828.27 mg/L) in WWTP 2, on the other hand, shows no significant ($P > 0.05$) differences between 796.05 mg/L in July, 811.84 mg/L in September and 823.60 mg/L in November 2018. This points to the fact that the TDS values in WWTP 2 are generally higher than what is obtainable in WWTP 1.

The concentrations of TDS (742–774 mg/L) in about 60% of the sampling periods in WWTP 2 are fairly stable and they did not show any significant differences ($P > 0.05$). This could probably point to a level of stability in the quantity of salts content that flow to the plant as a result of stability in the lifestyle of people around the WWTP 2. It could also suggest a level of precision, stability or efficiency of the treatment plant in removing dissolved solids. Comparing the two plants, we could say that WWTP 1 is more efficient than WWTP 2 in removing TDS.

The lowest concentrations of TDS recorded in both plants (WWTP 1 (590.72 mg/L; WWTP 2 (694. 83 mg/L) within the sampling period is in proximity to the average TDS (644.5 mg/L) obtained from effluents from engineering industries from Taloja Industrial Area of Mumbai, India (Lokhande et al. 2011).

TDS is a measure of water salinity and it determines the concentration of salts a water body contains. These mainly include carbonates, bicarbonates, chlorides, sulfates, phosphates and nitrates of calcium, magnesium, sodium, potassium, iron and manganese (Rusydi 2018). The density of water can be greatly affected by the quantity of dissolved solid elements in it. This can consequently impact osmoregulation in aquatic organisms, reduce the solubility of gases (like oxygen) and thus determine the application/uses of such water (Qadir and Chhipa 2015).

Earlier study sub-divides TDS into different categories according to the concentration of TDS which includes: appropriate for drinking (maximum TDS, 500 mg/L), tolerable for drinking (500–1000 mg/L), suitable for irrigation (1000–2000 mg/L), not suitable for drinking and irrigation (above 3000 mg/L) (Lokhande et al. 2011). Considering the TDS ranges in WWTP 1 (590.72–813.01 mg/L) and WWTP 2 (694.83–828.27 mg/L), the effluent in the two plants can

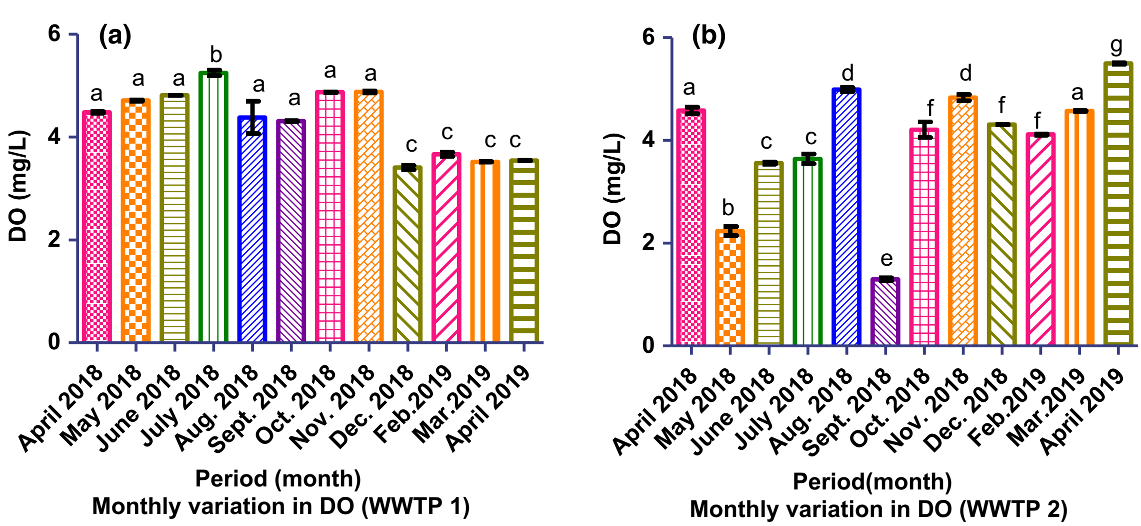

Fig. 6 Monthly variation of DO in WWTP 1 and 2

be considered fit for irrigation purposes particularly if other parameters are within the permissible level. This is corroborated by the previous study that water containing TDS less than 1000 mg/L could be considered appropriate for irrigational purposes as this would not affect the osmotic pressure in soil solution (Oyem et al. 2014).

Monthly variation of DO in WWTP 1 and 2

Figure 6 illustrates the monthly variation of DO for WWTP 1 and 2 that ranged between 1.30 and 5.50 mg/L. The lowest and highest DO were both recorded at WWTP 2. The lowest DO concentration in September (1.30 mg/L) in WWTP 2 was significantly different from the DO content in any other months ($P < 0.05$). This could likely be due to the dredging activities that took place at the sampling site in September 2018.

The relatively high DO concentration recorded from October 2018 to April 2019 in WWTP 2 could probably be due to the longer duration of bright sunlight during the long day in spring/summer/autumn. This conformed with the report of Patil and co-workers that the longer day and bright sunlight experienced during summer promotes photosynthesis by phytoplankton which consumes carbon dioxide and releases more oxygen into the water body (Patil et al. 2012). On the other hand, a lower DO value (3.41–3.67 mg/L) was recorded around the same period (December 2018 to April 2019) in WWTP 2 compared to what was obtained in the earlier part of the sampling period. This could be attributed to the presence of inorganic compounds present in the effluent from the surrounding industries. Previous study reported that inorganic compounds such as ammonium nitrites, hydrogen sulfates and ferrous ions present in water could compete for oxygen in water, thereby lowering its DO content (Agoro et al. 2018).

Past findings reported that DO is a parameter for measuring the level of pollution by organic matter, it guides the physical and biological activities in water such as the rate of decomposition of organic substance (Osuolale and Okoh 2015; Agoro et al. 2018). The discharge effluents with low dissolved oxygen, high BOD and turbidity are an indicator of potential danger to the receiving surface water. Low concentrations of dissolved oxygen, when combined with the presence of toxic substances, could constitute a stress to aquatic ecosystems because the toxicity of some elements increases with low concentrations of DO (Osuolale and Okoh 2015). The acceptable DO standard for aquatic organisms is 4–5 mg/L (Agoro et al. 2018), the result from the two WWTPs shows that about 67% of the recorded DO values (4–5 mg/L) is good for aquatic life. However, the DO values in both plants (1.3–5.50 mg/L) ranged below the recommended limits for both DWAF (7.5 mg/L) and USEPA (6–9 mg/L).

Monthly variation of SO_4^{2-} in WWTPs 1 and 2

Figure 7 presents the monthly variation of SO_4^{2-} in WWTPs 1 and 2. The SO_4^{2-} concentrations in the two WWTPs ranged between 3.23 and 163.18 mg/L in June 2018 and November 2018, respectively, within the sampling period. Both the lowest and highest SO_4^{2-} levels were recorded in WWTP 1. The result shows a level of variation within the sampling period. The concentrations of SO_4^{2-} in April

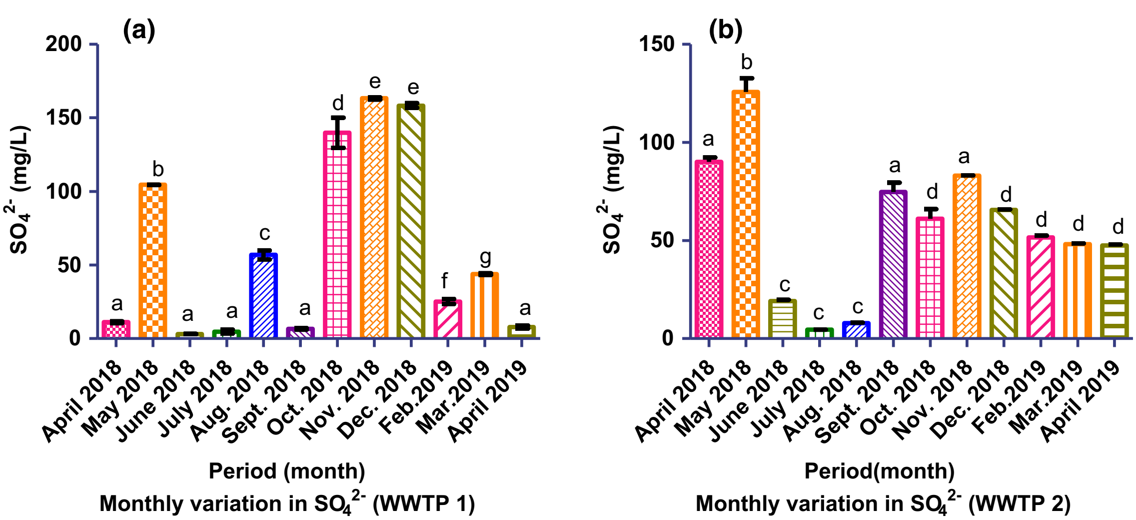

Fig. 7 Monthly variation of $SO4^{2-}$ in WWTPs 1 and 2

2018, June 2018, July 2018, September 2018 and April 2019 were very low (3.23–11.21 mg/L). Similar results were also obtained in June 2018 (19.18 mg/L), July 2018 (4.62 mg/L) and August 2018 (7.93 mg/L) in WWTP 2. This could be ascribed to a high level of organic matter in the wastewater leading to a low level of dissolved oxygen in the wastewater. An earlier report showed that if an aquatic environment is deprived of oxygen, sulfate being an electron acceptor could be used to break down the organic matter present in water to produce hydrogen sulfide with rotten egg smell (Kavitha et al. 2012). The concentrations of sulfate in other months in both plants were higher within the sampling period. This is likely to be associated with excessive use of detergent and soap in WWTP 1. Likewise, cartridge wastes containing ink and barium sulfate used as additive both from plastic industries could be responsible for the high level in WWTP 2 (Shrestha et al. 2017).

The values in both plants within the sampling period are lower than 300 mg/L reported by Kavitha and his team for effluent from a pharmaceutical industry (Kavitha et al. 2012). It was, however, higher than the 15.97–87.38 mg/L reported for wastewater effluent in Nullah Lai and Koh-e-Noor textile in Pakistan (Iram et al. 2013). The normal level of sulfate in the water had been reported to be optimal for the plant need, a low level of SO_4^{2-} could cause laxative in human and excessive sulfate in water could lead to diarrhea and other gastrointestinal diseases (Kavitha et al. 2012; Agoro et al. 2018). The level of sulfate in both WWTPs fell within the recommended limits by both DWAF (200 mg/L) and 250 mg/L by USEPA Table 2.

Monthly variation of COD in WWTPs 1 and 2

Figure 8 presents the monthly variation of COD in WWTP 1 and 2 within the sampling period. The result from the two WWTPs showed that the COD concentration ranged from 23.70–898.58 mg/L in WWTP 1 and 2, respectively. The result shows that the concentration of COD in WWTP 1 was generally lower compared with that in WWTP 2. The value of COD obtained in 50% of the sampling period in WWTP 1 in April 2018 (24.75 mg/L), July 2018 (23.70 mg/L), September 2018 (54.35 mg/L), October 2018 (35.49 mg/L), November 2018 (66.33 mg/L) and February 2019 (33.33 mg/L) falls within the recommended values for DWAF (75 mg/L) for wastewater discharge but all the levels in WWTP 2 are higher than the permissible limit of 75 mg/L by DWAF. As per the USEPA recommended limit, the COD level in both plants complies with the limit (< 1000 mg/L) set by USEPA.

This indicates that WWTP 1 was a little effective in removing COD pollution than WWTP 2. The higher level of COD in WWTP 2 could be associated with high population density and illegal dumping of organic materials due to the high level of informal settlement around WWTP 2.

The concentrations of COD (23.70–898.58 mg/L) in the two plants within the sampling period were lower compared to 352–927 mg/L reported for the final effluents from Waluj industrial area in Indian (Kale and Bandela 2016). The values were however higher than 46.80–93.60 mg L reported for Boji Owa and Owa-Alero in Nigeria (Oyem et al. 2014). COD test determines the level of domestic and industrial pollution in wastewater. It measures the amount of oxygen necessary to oxidize organic matter in water under specified conditions of oxidizing agent usually potassium dichromate and temperature (150 °C) for 2 h (Kale and Bandela 2016).

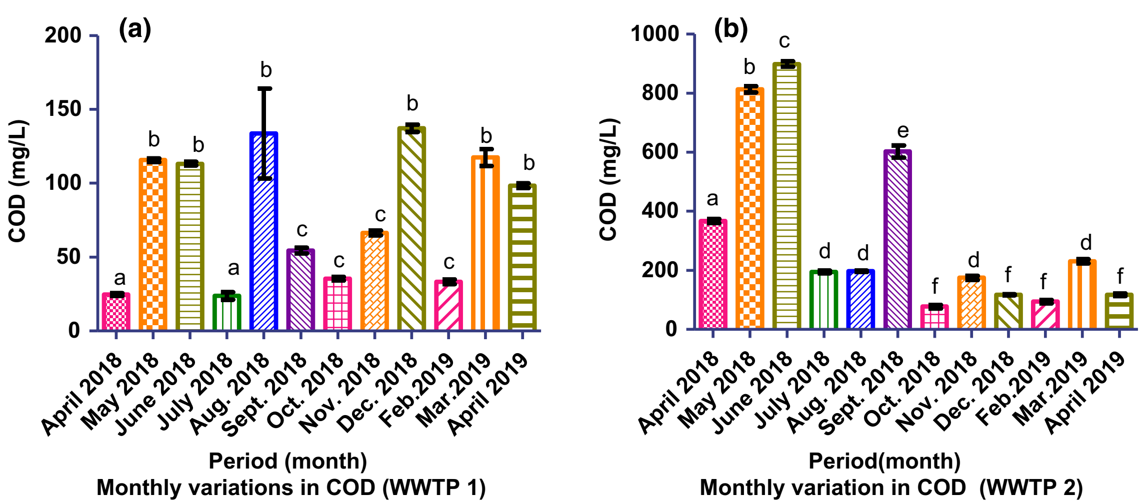

Fig. 8 Monthly variation of COD in WWTPs 1 and 2

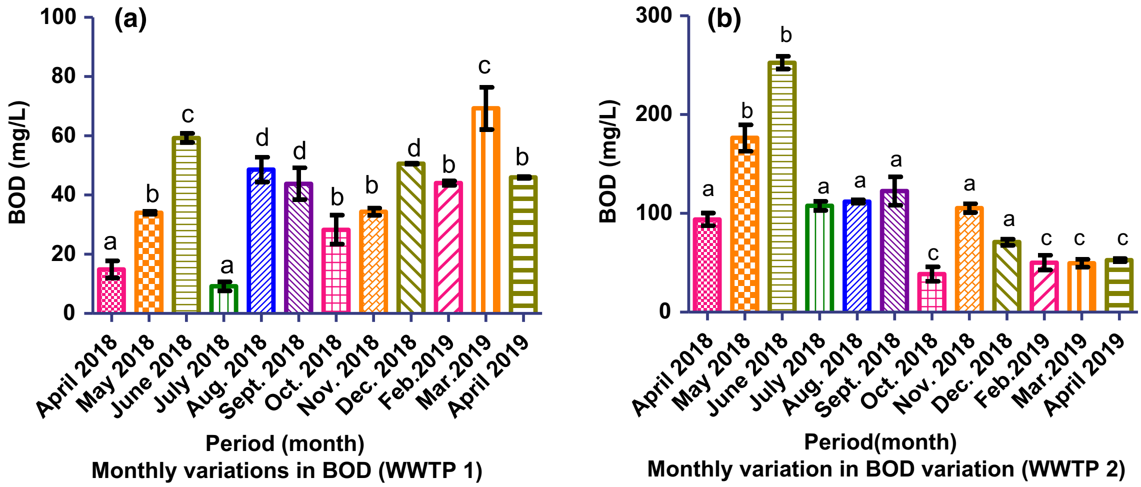

Fig. 9 Monthly variation of BOD in WWTP 1 and 2

High quantity of COD is an indication that the effluent could contain hazardous materials that are resistant to microbial degradation and these are dangerous to the receiving water bodies (Paltahe et al. 2018).

Monthly variation of BOD in WWTP 1 and 2

The monthly variation of BOD in WWTPs 1 and 2 is presented in Fig. 9. As shown in the figure, the BOD levels ranged between 9.17 and 252.44 mg/L in July 2018 and March 2019, respectively. The lower level of BOD could arise from the effectiveness of WWTP 1 efficiency in removing organic matter (Osuolale and Okoh 2015). The high level of BOD, particularly in WWTP 2, could be the result of direct discharge of plants, animals and other domestic waste into the sewage system by the residents which dwell mostly in an informal setting around WWTP 1 (Paltahe et al. 2018). The concentration range (9.17–252.44 mg/L) in both plants is higher compared to that 3.7–14 mg/L reported for effluent from municipal wastewater from Eastern Cape, South Africa (Adewumi et al. 2010; Agoro et al. 2018). The values in both plants were however lower compared to 535.80 mg/L and 604.80 mg/L reported by Lokhande et al. (2011) for wastewater effluents from paint and engineering industries, respectively. These values were also lower than 776.2 mg/L and 535.8 mg/L reported for effluents from dyes and paint industries, respectively (Paltahe et al. 2018).

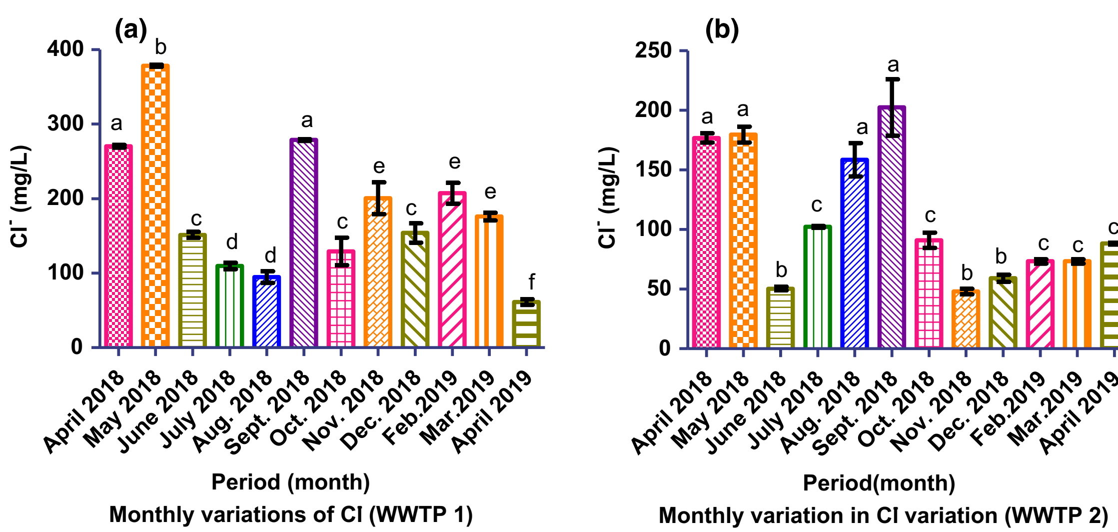

Fig. 10 Monthly variation of Cl^- in WWTP 1 and 2

The BOD in both treatment plants are far above the recommended limit of 3–6 mg/L for the discharged effluent by DWAF but all of them fell within the 500 mg/L limit set by USEPA Table 2. Based on the result obtained in the two plants, the levels of BOD in WWTP 2 (38.54–252.44 mg/L) were generally higher than the values in WWTP 1 (9.17–69.25 mg/L). Low BOD content in water suggests good and qualitative water. High BOD concentration indicates a high level of organic matter content and this signifies potential danger to the receiving water bodies. This reduces the quantity of dissolved oxygen available in water and constitutes a potential risk to aquatic organisms in the water body (Osuolale and Okoh 2015; Paltahe et al. 2018).

Monthly variation of Cl^- in WWTP 1 and 2

Figure 10 illustrates the monthly variation of chloride ion in WWTP 1 and 2 within the sampling period of April 2018 and April 2019. The chloride concentration in both plants ranged between 48.17 mg/L in WWTP 2 and 378.48 mg/L in WWTP 1, respectively. The lowest concentration (48.17 mg/L) observed in WWTP 2 was not significantly different from 50.60 mg/L and 59.19 mg/L in June 2018 and December 2018, respectively, but differed significantly from what was recorded in other months within the sampling period in WWTP 1. The highest concentration observed in May in WWTP 1 was significantly different from the concentration in other months. The chloride variation in the two plants showed that the concentration of chloride in WWTP 1 is higher than what was obtainable in WWTP 2. About 20% and 75% of the chloride concentration recorded in WWTP 1 complies with the recommended limit by DWAF (100 mg/L) and USEPA (250 mg/L), respectively. It was also observed that 80% and 100% of the chloride concentrations in WWTP 2 were within the DWAF (100 mg/L) and USEPA (250 mg/L) limits, respectively. The results obtained in these plants were higher than 3.25–224 mg/L reported by Agoro et al. (2018) but lower than (127.72–396.16 mg/L) reported by Iram and colleagues from wastewater effluents from Nullah Lai and Kohe-Noor textile in Pakistan (Iram et al. 2013).

Sodium chloride that enters the wastewater treatment plant is a major component of the human diet; they are readily soluble in wastewater and not significantly affected by wastewater treatment processes (Chigor et al. 2013). Above 250 mg/L of sodium chloride in water, the water becomes unpleasant due to the salty taste and also unfit for irrigation purposes (Chigor et al. 2013). In an aquatic ecosystem, high chloride content can threaten the sustainability of ecological food sources, thereby constituting a risk to species survival since it affects growth and reproduction among some aquatic organisms (Aniyikaye et al. 2019).

Monthly variation of PO_4^{3-} in WWTPs 1 and 2

Figure 11 presents the monthly variation of phosphate in WWTPs 1 and 2. The concentrations varied from 0.10 mg/L in September 2018 to 11.32 mg/L in November 2018. The lowest and highest concentrations were observed in WWTP 1. This shows a great variation in the phosphate concentration in WWTP 1 than WWTP 2. The phosphate concentrations range obtained in plant 2 was more consistent

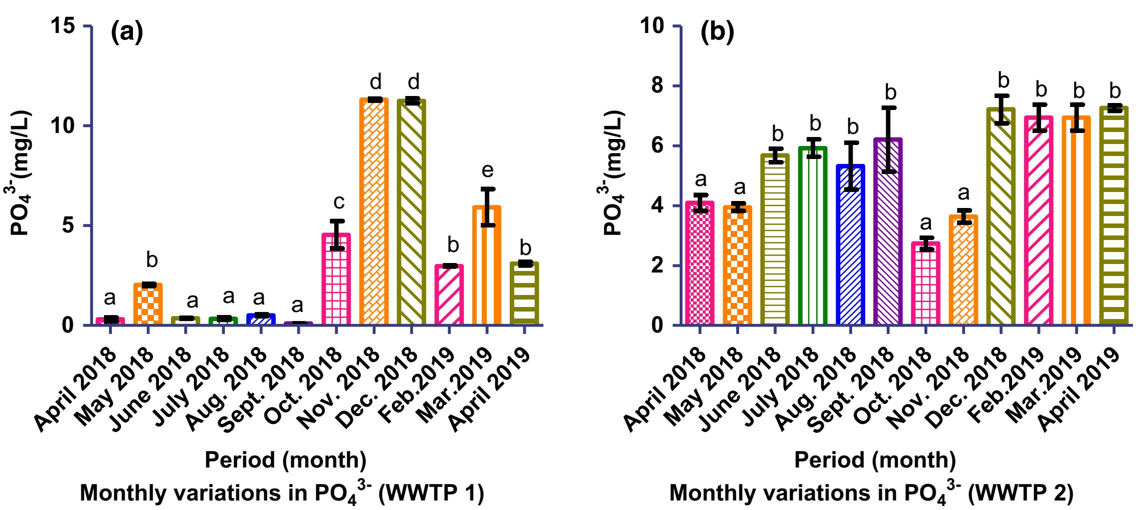

Fig. 11 Monthly variation of $PO4^{3-}$phosphate in WWTPs 1 and 2

within the sampling period level as shown in Fig. 11. The concentrations (0.1–0.51 mg/L) in the first 6 months of the sampling period (except May 2018) were very low. A sudden rise in the concentration of PO_4^{3-} occurred in October 2018 and continued for the rest of the sampling period. A similar trend was also observed in the last 4 months in WWTP 2. This can be attributed to excessive use of fertilizers for agricultural purposes, effluent from food and meat processing industries and undue detergent waste disposal from households. A similar trend was observed by Shrestha et al. (Shrestha et al. 2017).

The concentration ranges recorded in major parts of the sampling period (10 months in WWTP 1 and 8 months in WWTP 2) in the two plants were comparable to 0.04–5.00 mg/L reported for wastewater effluent by Agoro et al. (2018). Nearly all the phosphate concentrations in the two plants comply with the DWAF set limit of 10 mg/L. Based on USEPA standard, 8 months (about 70%) comply in WWTP 1 while only 3 months comply in WWTP 2 as shown in Table 2. The range of the PO_4^{3-} in the entire sampling period was close to (1.21–9.92 mg/L) reported for five wastewater effluents from an industrial area in Nepal (Shrestha et al. 2017). Reports have shown that high concentrations of phosphate and nitrates promote enhanced eutrophication in the aquatic ecosystem and hence increase oxygen demand which can cause several objectionable ecological problems in the ecosystem (Agoro et al. 2018; Paltahe et al. 2018).

Conclusion

The results obtained from this study showed that temperature, pH and SO_4^2 in the two plants complied with the recommended limits by DWAF and USEPA. EC, COD and BOD values in both plants conformed with the USEPA limits only. Chloride and phosphate levels in WWTP 2 were within the recommended limits by USEPA (250 mg/L) and DWAF (10 mg/L), respectively. Only three out of the ten parameters studied fully complied with the recommended limits by both regulatory bodies indicating that effluents from these plants are sources of pollution to the receiving water bodies and environment at large. Therefore, some of the specific objectives of national guideline values, including access to clean and safe water, prevention of health-related waterborne diseases and eradication of gross pollution to surface water sources were not fully met. This is not good for a semi-arid country like South Africa where water is scarce and wastewater effluent is used in agriculture, landscaping and industrial purposes. This study, therefore, suggests an urgent need to upgrade these plants and any other existing WWTPs in Cape Town, South Africa. Routine pollution monitoring of the WWTPs and strict enforcement by national regulatory organizations to ensure compliance with the set standards are also recommended. This will go a long way to stop or minimize the risk of pollution to the receiving water bodies thus ensuring a safe and healthy environment to residents of Cape Town and the entire South Africans.

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