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Physicochemical, Nutrient, and Heavy Metal Characterization of Wastewater Released from Wachemo University, SNNPR, Ethiopia

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ABSTRACT: Waste management in higher educational institutions is an existing environmental challenge in Ethiopia. Thus, this study aimed to determine the physicochemical, nutrient, and heavy metals concentration of wastewater generated from Wachemo University, SNNPR, Ethiopia. Three wastewater samples were collected and placed in a refrigerator until sample preparation and analysis. Physicochemical parameters, nutrients, and heavy metals were measured using the Standard Methods of the American Public Health Association. The results of the study were ranged as Temperature (19.00–19.02 ºC), TDS (89.9–201 mg/L), E.C (179.9–284 µS/cm), DO (1.5–4.5 mg/L), Turbidity (93.2–513.8 NTU), pH (4.82–7.48), TSS (458.4–143 mg/L), TS (339.7–3889.6 mg/L), BOD (44.9–287.1 mg/L), COD (144.9–869.7 mg/L), phosphate (5.2–13.0 mg/L), sulfate (0.02–280.3 mg/L), nitrate (47.9–54.0 mg/L), NH_3–N (0.03–7.39 mg/L). The values of most of the physicochemical parameters, nutrients, and heavy metals are within the permissible limit of FAO and EEPA. However, the concentration of Pb was found to be above the maximum permissible limit set by WHO. Similarly, the values of physicochemical parameters such as BOD, COD, TSS, and E.C were above the acceptable range for wastewater discharged limit set by FAO and EEPA. Thus, the result showed that the wastewater released from Wachamo University pose a risk to the surrounding environment and human health unless a proper waste management system is implemented.

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Higher Education Institutions (HEIs) such as universities can produce a wide diversity of waste including construction and demolition waste, electronic waste, office waste, lamp, furniture, and metal waste, food waste, hospital waste, etc., that will impact the environment (Moqbel, 2018; Gebreeyessus *et al.*, 2018; Oladejo *et al.*, 2018; Adeniran *et al.*, 2017; Zen *et al.*, 2016; Mu *et al.*, 2017). This is because Universities have a population size that can be recognized as a small community and can generate a significant amount of various wastes (Abas and Seow, 2014; Armijo *et al.*, 2003; Taghizadeh *et al.*, 2012) which influence the environment either directly or indirectly. As a result, Universities should follow a proper waste management system to dispose of the wastes generated in their teaching and research activities, since they are composed of a great variety of substances, potentially toxic and harmful, which should go through adequate treatment before being disposed of, aiming to avoid environmental problems and contamination of living beings (Mora *et al.*, 2016; Moreira *et al.*, 2018; Tancharoen and Rachakornkij, 2018). Thus, Higher Education Institutions such as universities have moral and ethical obligations to apply sustainable waste management (Gallo, 2017) to reduce the impact of waste on the surrounding environment. Higher Education Institutions such as research institutions and laboratories around the world have been working on the implementation of good chemical waste management practices to reduce the risks of accidents and human and environmental contamination (Ho and Chen, 2018; Pourzamani, 2019). However, in Ethiopian Higher Educational Institutions, waste management particularly liquid waste management is an existing environmental challenge (Alemayehu *et al.*, 2014). Thus, this study aimed to determine the physicochemical, nutrient, and heavy

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metals composition of wastewater generated from Wachemo University, one of the third generations of Ethiopian Universities, located in the Hadiya zone, SNNPR, which has no advanced waste management system that appropriately deals with all types of waste. The liquid waste generated from the university is channeled into the nearby river without any treatment which poses potential environmental pollution and health problems. Therefore, the objective of this study is to evaluate the physicochemical, nutrient, and heavy metal characterization of wastewater released from Wachemo University.

MATERIALS AND METHODS

Description of the Study area: The study was conducted at Wachemo University, the third generation of Ethiopian Universities, located in the Hadiya zone, SNNPR, Ethiopia, located about 232 km from the south of Addis Ababa Ethiopia. It is located at 7° 33' 14" N latitude and 37° 53' 2" E longitudes. This location is characterized as a sub-humid climate and has an extended period of the wet season from March to October, in addition to the main rainy season from July to September and a mean annual temperature of 20 °C and annual average rainfall ranging from 920.4 mm to 1436.5 mm. Established in 2009 and commenced its function in 2012. It has three campuses, seven agricultural and technology transfer centers, seven teaching centers, and eight schools, with 57 undergraduate study programs. Wachemo University is also equipped with various facilities, including a student dormitory, hall, stadium, several commercial areas, a hospital, and an ISWPF. Wachemo University mainly performs activities in academia, research, and community services. Currently, the University has admitted over 18,400 students into regular and continuing education programs. The location map of the study area is shown in Figure 1.

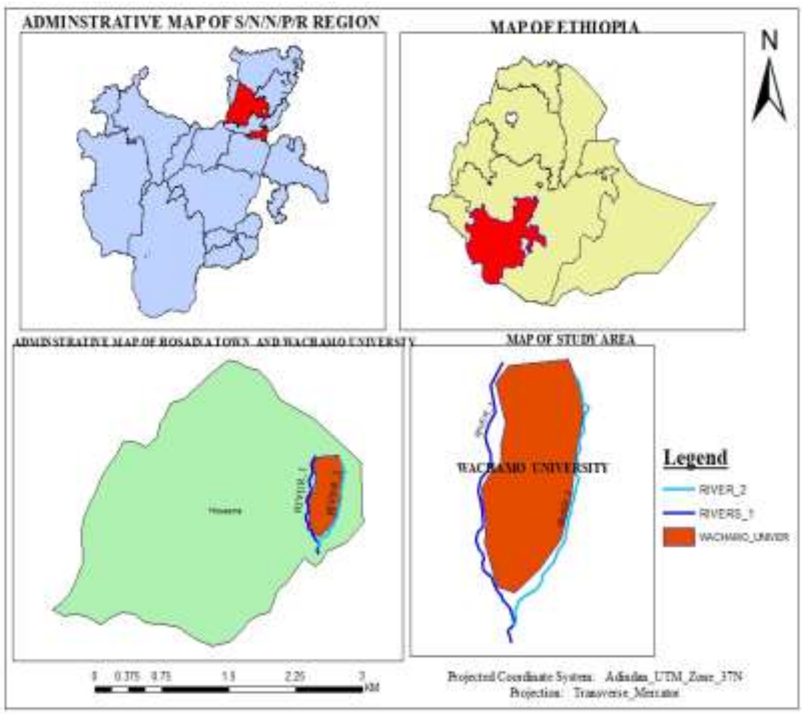

Fig 1: Location map of the study area

Sample collection, preparation, and analysis: According to the field survey conducted in the sampling area, Wachemo University generates waste from its various activities such as agriculture and animal breeding center, laboratory rooms, bathrooms, toilet rooms, sewage, and student cafeteria. Particularly, the liquid wastes are discharged completely untreated into a big culvert that drains into the nearby rivers and this river water are used up to grow vegetables in the nearby area of the Wachemo University near the river beads. This might cause harmful effects to the environment and human health, including undesirable changes to ecosystems and human health risks. Thus, sample collection was carried out after the field survey has been completed. Three sampling sites have been selected. These were Sample Site one (S1) which refers to the wastewater entry point near Batena river, which is found around Wachemo University, where a large amount of raw wastewater (chemical and domestic liquid waste) has been discharged to the river; Sample site two (S2) which refers to a septic tank, where wastes from student's cafes are being neutralized and released into the river; Sample site three (S3) refers to a nearby pond where a large number of liquid wastes from various sources are being dumped into it. All wastewater samples were collected and preserved according to the standard methods for the examination of wastewater (APHA, 2005). Wastewater samples were collected in triplicate using a universal sample bottle (sterile) of 500 mL capacity. The collected wastewater samples were stored at a temperature below 4 °C in an ice box containing ice freezer packs before laboratory analysis. The collected wastewater samples were filtered using glass fiber filter paper before analysis for, NH_3-N and NO_3^- whereas analysis of TSS, and COD were done from unfiltered samples. The physicochemical parameters analyzed were pH, temperature, DO, BOD, COD, TS, TDS, TSS, EC, turbidity, NO_3^-, PO_4^{-3}, SO_4^{-2}, and NH_3-N. The concentrations of heavy metals (Cu, Pb, Mn Cr, and Co) in the wastewater samples were determined using FAAS. The method or instruments used to measure the physicochemical parameters were summarized in Table 1.

Table 1: Instruments or methods used for the determination of physicochemical parameters

Parameter	Instrument/Methods
pH	HQ40d Multimeter (HACH LANGE, NV)
Temperature	HQ40d Multimeter (HACH LANGE, NV)
DO	HQ40d Multimeter (HACH LANGE, NV)
ABOD	BOD HACH Track instrument (DR/2010 HACH, Loveland, USA)
COD	Digestion of potassium dichromate in a DR/2400 HACH digester at 150 °C for 2 hrs.
TDS	The gravimetric method dried at 105 ^{0}C for 24 hrs.
TSS	The gravimetric method dried at 105 ^{0}C for 24 hrs.
TS	Nephelometric turbidity meter
EC	Jenway model 4510 conductivity/temp meter (451001)
Turbidity	Turbidimeter HACH 21009
Nitrate, phosphate, sulfate, NH_3-N	Hach Lange kits using HACH DR/2800 spectrophotometer
Heavy metals	FAAS (BUCK SCIENTIFIC, Model 210VGP AAS, USA)

Data analysis: Descriptive statistics and graphical analyses were used to summarize and display the values of the physicochemical parameters in the wastewater samples. One-way analyses of variance (ANOVA) tests were used to distinguish whether the differences among wastewater sampling sites were significant. Microsoft Excel was used to create the graphs

RESULTS AND DISCUSSION

Assessment of the physicochemical and nutrient characteristics of wastewater from the sampling sites: A statistical summary of the physicochemical parameters of wastewater samples taken from the three sampling sites (S1, S2, and S3) is shown in Table 2. The average values of the physicochemical parameters analyzed in each sampling site is shown in Figure 2.

pH: pH values were approximately the same at the two sampling sites except for sampling site S2 showed a slightly acidic pH (4.82). This might be due to ions that are dissociated from domestic wastes and agricultural runoff. The pH value of sampling sites 1 and 3 was within the range of EEPA pH standard. At a 95% confidence level, the values of pH were significantly different among the sampling sites ($p < 0.05$).

Table 2: Results of wastewater physicochemical parameters (Mean ± SD, n=3) for the sampling sites. All units are in mg/L except pH (pH scale), temperature (°C), turbidity (NTU), and EC (µS/cm).

Parameters	Sample Site			WHO, 2008	EEPA, 2003	FAO, 1994
	S1	S2	S3			
pH	7.48 ± 0.01	4.82 ± 0.01	6.64 ± 0.01	6.5–8.5	6–9	6.0–8.5
Temp.	19.12 ± 0.01	19.0 ± 0.01	19.2 ± 0.04	< 40	40	--
DO	4.50 ± 0.02	1.50 ± 0.01	1.50 ± 0.02	--	≥ 4	--
BOD	44.94 ± 0.02	287.10 ± 0.06	113.10 ± 0.02	500	≤ 25	2000
COD	144.9 ± 0.33	869.70 ± 0.60	289.94 ± 0.13	--	≤ 150	--
TDS	89.94 ± 0.12	201.0 ± 1.00	186.9 ± 0.53	5.0–7.0	--	> 4.0
TSS	1433.0 ± 1.5	458.4 ± 1.1	563.0 ± 1.15	2.0–5.0	≤ 50	8.0
TS	3889.6 ± 0.8	2228.4 ± 1.6	339.70 ± 1.47	--	--	--
EC	179.9 ± 0.21	284.0 ± 0.2	237.93 ± 0.06	750	1000	3000
Turbidity	513.8 ± 0.15	93.24 ± 0.14	128.98 ± 0.17	5.0	--	--

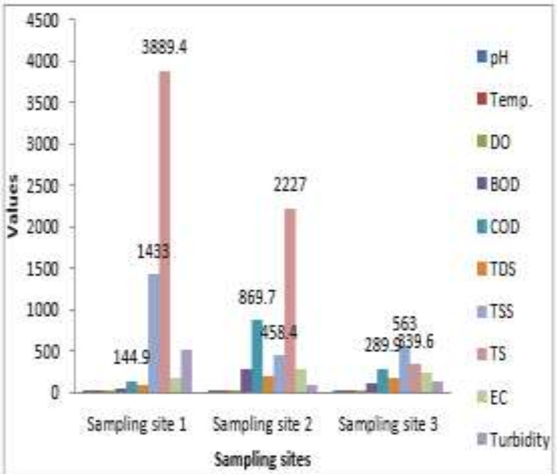

Fig 2: Average values of the physicochemical parameters analyzed in wastewater samples taken from the sampling sites. All units are in mg/L except pH (pH scale), temperature (°C), turbidity (NTU), and EC (μS/cm).

Temperature: Temperature is an important indicator of water quality regarding the existence and survival of aquatic organisms. Temperature does have a direct effect on other parameters of wastewater such as pH, redox potentials, the solubility of metals, and a variation in temperature influences the metabolic rate of organisms, etc. The recorded values of temperature for the selected wastewater samples S1, S2, and S3 were 19.12, 19.0, and 19.2, respectively. The temperature values in all sampling sites were not significantly different at a 95% confidence level. The average temperature value was within the permissible limit of WHO. This result is similar to other studies reported within the range of 19.0–23.9 ^{o}C (Okweye *et al.*, 2013). Thus, the average temperature of the wastewater is favorable for the aquatic ecosystem.

Dissolved oxygen (DO): Dissolved Oxygen plays the role of regulator of metabolic activities of organisms and thus governs the metabolism of the biological community as a whole and is used as an indicator of the trophic status of the water (Sinha, 2011). A concentration level of DO below 5.0 mg/L is adversely affecting aquatic life (Tennessee Valley Authority, 1995). In the present study, DO values ranged from 1.50 to 4.5 mg/L. A minimum value was recorded in Site 2 that indicates the sampling site (Site 2) is a receiver of wastewater from the student's cafeteria. The maximum value was recorded in Site 1 which might be due to the self–the purification of the water along the course of the wastewater. DO values among the sampling sites were significantly different at a 95% confidence level ($P < 0.05$).

Biochemical oxygen demand (BOD5): BOD is a measure of the amount of oxygen requires by bacteria for breaking down to simpler substances of the decomposable organic matter present in any water, wastewater, or treated effluent. It is also taken as a measure of the concentration of organic matter present in any water. The greater the decomposable matter present, the greater the oxygen demand and the greater the BOD values (Burns, 2002). BOD values range from 44.94 to 287.1. The BOD values of the wastewater, except for Site 2, were within the recommended values of WHO and FAO. The high BOD value recorded in Site 2 could be an indication of organic pollution due to loads of wastewater from the students' café and it might also indicate a low amount of oxygen available for living organisms in the wastewater due to the use of oxygen to decompose the organic matter present. Similarly, other findings also showed that a high level of BOD causes to decrease in the value of dissolved oxygen in the surrounding water bodies (Ubwa *et al.*, 2013). One-way ANOVA analysis showed that at a 95% confidence level, Site 2 was significantly different in BOD value from the other sites.

Chemical oxygen demand (COD): COD is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as ammonia and nitrite. COD test measures the oxygen demand of biodegradable pollutants plus the oxygen demand of non–biodegradable oxidizable pollutants. COD is a water quality measure used not only to measure the amount of biologically active substances such as bacteria but also biologically inactive organic matter in water (Khuhawari *et al.*, 2009). COD is another measure of organic material contamination in water specified in mg/L. COD is the amount of dissolved oxygen required to cause chemical oxidation of the organic material in liquid wastewater. Both BOD and COD are indicators of the environmental pollutants of wastewater/surface water bodies. Chemical oxygen demand measures are commonly made on samples of wastewaters or of natural waters contaminated by domestic or industrial wastes. The COD mean values in this study were 144.9 ± 0.33 mg/L at Site 1, 869.7 ± 0.6 mg/L, at Site 2, and 289.94 ± 0.13 mg/L at Site 3, respectively. COD values varied significantly among sampling sites ($p < 0.05$, ANOVA) and ranged from 144.9 to 869.7 mg/L. The higher value of COD implies a greater amount of oxidized organic material in the sample that reduces dissolved oxygen level and endangers the surface water bodies/river life.

Total dissolved solids (TDS): TDS can be taken as an indicator of water quality parameters because it directly affects the aesthetic value of the water by increasing turbidity. TDS tells us the amount of both organic and inorganic dissolved compounds which may remain persistent and result in a cumulative toxic effect (Saksena and Kaushik, 1994). In this study, the average concentration of TDS at S1, S2, and S3 sample is 89.9 ± 0.12 mg/L, 201 ± 1.0 mg/L and 186.9 ± 0.12 mg/L respectively. The high value of TDS recorded in the wastewater might be due to agricultural runoff, discharge of wastes from the university, and other human activities like washing of different vehicles at and around the river (Sonja, 2010). Wastewater discharges with high TDS value may cause salinity problems if discharged into irrigation water. Some dissolved organic matter may contribute to an increased level, often TDS which also indicates that water is polluted (FAO, 1994). The results of TDS decreasing in concentration through the sampling points indicated that the solids were either adsorbed on the surface of the earth or desorbed into it. A high concentration of TDS may reduce the water clarity leading to a decrease in photosynthesis and when added to toxic compounds and heavy metals, leads to an increase in temperature. At a 95% confidence level, the values of TDS were significantly different among the sampling sites.

Total suspended solids (TSS): Suspended solid does not mean that they are floating matters and remain on top of the water layer. They are under suspension and remain in a water sample. Total suspended solids play an important role in water and wastewater treatment. Their presence in the water sample causes depletion of oxygen levels (Khan, 2012). The current study showed that the concentration of TSS in S 1, S2, and S3 samples are 1433.0 ± 1.0 mg/L, 458.4 ± 1.29 mg/L, and 563.0 ± 1.0 mg/L respectively. The average value of TSS ranged from 458.4 ± 1.29 mg/L to 1433 ± 1.0 mg/L. The highest value in S1 might be due to the use of a large amount of water for cleaning and removing dirty materials from the cafeteria, Student clinic, laboratory, etc. The statistical analysis at a 95% confidence level showed that there were significant differences in TSS value among the sampling sites.

Total solids (TS): In the presence of high total solids, water is heating up more rapidly and holds more heat, which in turn, adversely affects aquatic life that has been adapted to a lower temperature regime. Low concentrations of total solids can also result in limited growth of aquatic organisms due to nutrient deficiencies (FAO, 1994). High total solids affect the light penetration. Irrigation water quality is evaluated based on total salt content. In this study, a high value of TS was recorded in the ranges of 339.7 ± 1.47 mg/L to 3889.6 ± 0.8 mg/L which is beyond the permissible limits of WHO and below the standards set by FAO for irrigation. The statistical analysis at a 95% confidence level showed that there were significant differences in TS value among the sampling sites ($p < 0.05$). Sites 1 and 2 showed a high amount of TS which might be due to the entry of agricultural runoff containing fertilizer and suspended soil particles and effluent discharged from Wachemo University.

Electrical conductivity (EC): (EC) is a measure of water capacity to convey electric current. The recorded EC values for the studied sites ranged from 179.9 ± 0.2 to 284 ± 0.2 µS/cm which is higher than the permissible limit by WHO and lower than the limit set by FAO for irrigation purposes. Thus, the result indicated that the generated wastewater receives a high amount of dissolved inorganic substances in an ionized form in their surface catchments. The statistical analysis at a 95% confidence level ($p > 0.05$) showed that there were no significant differences in EC value among the three sampling sites.

Turbidity: In most waters, turbidity is due to colloidal and extremely fine dispersions. In many aquatic systems, water clarity is determined by the abundance of suspended algae. Eutrophic systems (containing high nutrient concentrations) support large algal populations, which reduce the clarity of the water and increase its color. In extreme cases, turbid water can harm animals and deposit heavy sediment on leaves, reducing photosynthesis (Shrinivasa and Venkateswaralu, 2000). Turbid water also affects how well disinfection techniques including ultraviolet light and chlorination work, and slows the establishment of vegetables. In the present study, the average turbidity values of the three sampling sites ranged from 93.24 ± 0.14 to 513.8 ± 0.15 NTUs. Turbidity values from all sampling sites were above the permissible limit set by WHO and FAO for irrigation water. The statistical analysis at a 95% confidence level indicates that Sites 1 and 3 were significantly different from site 2. This might be due to the entry of agricultural runoff and domestic and municipal wastes. Thus, the entire wastewater was generally polluted posing a great danger to aquatic lives and the people using it for domestic and irrigation purposes.

Assessment of the Nutrient composition of wastewater from the three sampling sites: A statistical summary of the nutrient concentration of wastewater samples taken from the three sampling sites (S1, S2, and S3) is shown in Table 3. The average concentration of nutrients in each sampling site is shown in Figures 3.

Nitrate: Nitrate represents the most oxidized form of nitrogen and the product of oxidation of nitrogenous matters and its concentration may depend on the nitrification and de-nitrification activities of microorganisms. The concentration of nitrate was recorded in the range of 47.93 ± 0.31 mg/L to 54 ± 0.20 mg/L. The value in Site 1 (47.93 ± 0.31 mg/L) was below the permissible limit of WHO. Maximum nitrate concentration was recorded at Site 3 (54.0 ± 0.20 mg/L) which was above the maximum permissible limit. This might be due to domestic sewage, and runoff from agricultural land that uses animal manure or nitrogen-containing fertilizer. High levels of nitrate and phosphate can lead to eutrophication, which increases algal growth and ultimately reduces dissolved oxygen in the water. Mean concentrations of nitrate in the sampling sites varied significantly ($P < 0.05$).

Table 3: Results of wastewater nutrient concentration (Mean ± SD, n=3) for the sampling sites.

Parameters	Sample Site			WHO 2008	FAO 1994
	S1	S2	S3		
Nitrate	47.93 ± 0.31	50.63 ± 1.18	54.0 ± 0.20	50	5
Phosphate	5.20 ± 0.04	10.6 ± 0.06	13 ± 0 .02	250	400
Sulfate	278.33 ± 1.60	280.30 ± 1.57	0.02 ± 0.02	45	50
NH_3-N	7.22 ± 0.02	0.03 ± 0.01	7.39 ± 0.03	0.1	2.0

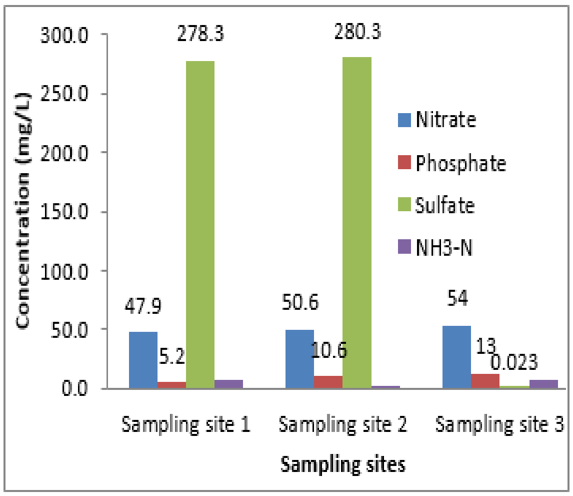

Fig 3: The average nutrient concentration of wastewater samples taken from the sampling sites

Sulfate: Sulfate occurs naturally in water as a result of leaching from gypsum and other common minerals. Discharge of domestic sewage tends to increase its concentration (Manivaskam, 2005). It is also an important constituent of hardness with calcium and magnesium and is one of the key nutrients in the aquatic environment. Sulfate is relatively common in water and has no major impact on the soil other than contributing to the total salt content. Irrigation wastewater high in sulfate ions reduces phosphorus availability to plants. Since the desired concentration level of sulfate for soil is less than 400 mg/L, higher than this value will acidify the soil. The concentration of sulfate ranged from 0.02 ± 0.02 mg/L to 280.30 ± 1.57 mg/L, which is lower than the permissible limit set by WHO and FAO. The statistical analysis at a 95% confidence level showed that there were significant differences in the concentration of sulfate among the sampling sites at ($p < 0.05$). The high value recorded at Site 2 also might be due to different wastes received from the domestic and surrounding of the university. Thus, generated wastewater in University and the surrounding not affect the surface water bodies or rivers also is suitable for drinking and irrigation purposes.

Orthophosphate: Phosphate determination is useful in measuring water quality since it is an important plant nutrient and may play a role as a limiting factor among all other essential plant nutrients. Phosphate comes from fertilizers, pesticides, industry, and cleaning compounds. Natural sources include phosphate-containing rocks and solid or liquid wastes. The lowest value of phosphate obtained was 5.2 ± 0.04 mg/L and the highest value was 13 ± 0.02 mg/L. For all sampling sites, the concentrations of phosphate were above the maximum limit set by the WHO standard. In this study, the maximum mean concentration of PO_4^{3-} was recorded at sampling site 3, which might be due to the discharge from soap and detergent wastes, domestic waste, fertilizers, and biological processes. The mean concentration of phosphate differed significantly ($P < 0.05$) among the sampling sites at a 95% confidence level.

Ammonia nitrogen (NH_3-N): The minimum concentration of ammonical nitrogen was found to be 0.03 ± 0.01 mg/L and the maximum concentration was 7.39 ± 0.03 mg/L. In water, ammonia exists in two forms ammonium ion (NH_4^+) and free ammonia (NH_3) depending on the pH of the water. At higher pH, ammonia is toxic to aquatic organisms and also for terrestrial organisms (Princic, 1998). The concentration of ammonia-nitrogen was above the maximum limit set by WHO standards for surface water. The reduction of ammonia downstream of the effluent discharge point has been attributed to the fact that at high pH, most ammonia was in a gaseous state, therefore, the gas volatilizes as the river flow. The mean concentration of ammonia differed significantly ($P < 0.05$) among the sampling sites. The high amount of ammonia causes an increase in pH and ammonical nitrogen concentration in the blood of the fish (Lawson, 2011). The high amount of ammonical nitrogen is more toxic in alkaline wastewaters than in acidic wastewater because free ammonia in high pH values is more toxic to aquatic biota than when it is in the oxidized form (Seyoum, 2003). Artificial fertilizers used by the local community might contribute to the presence of ammonia in the liquid wastewater under the study.

Assessment of the Heavy Metal composition of wastewater from the three sampling sites: A statistical summary of the concentrations of the heavy metals in the wastewater samples taken from the three sampling sites (S_1, S_2, and S_3) is shown in Table 4. The average concentration of heavy metals in each sampling site is shown in Figure 4.

Table 4: Heavy metal concentration (Mean ± SD, n=3) for the sampling sites.

Metals	Sample sites			EEPA 2003	WHO 2008	RMC (EEPA & FAO) for irrigation water
	S1	S2	S3			
Mn	0.085 ± 0.01	0.084 ± 0.03	0.065 ± 0.014	0.5	0.4	0.2
Cu	0.046 ± 0.002	0.07 ± 0.004	0.054 ± 0.02	2.0	2.0	0.2
Pb	0.025 ± 0.005	0.02 ± 0.01	0.0187 ± 0.006	0.01	0.01	0.2
Co	0.075 ± 0.003	0.05 ± 0.006	0.044 ± 0.01	--	--	--
Cr	0.073 ± 0.013	0.113 ± 0.03	0.17 ± 0.012	0.05	0.05	0.1

RMC = Recommended maximum concentration

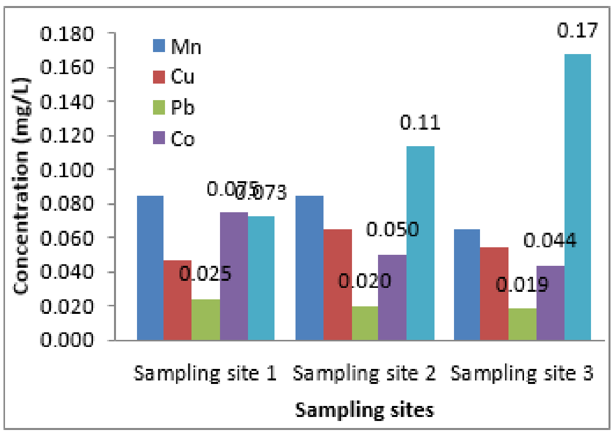

Fig 4: Average concentration of heavy metal in wastewater samples taken from the sampling sites

Manganese (Mn): The mean concentration of Mn ranges from a minimum value of 0.065 ± 0.014 mg/L at Site 3 to a maximum value of 0.085 ± 0.03 mg/L at Site 2. Mn concentrations from all sites were below the minimum permissible limit value set by WHO for wastewater/surface water. However, a maximum value of 0.085 ± 0.03 mg/L was recorded at site 3. This might be due to the natural deposition of Mn-containing compounds because the major sources of Mn pollution come from atmospheric deposition, contamination of water in natural geologic deposition, and discharge of municipal waste and domestic waste. Statistical results from ANOVA ($P > 0.05$) show that the mean concentration of Mn was not significantly different among the sampling sites at the 95% level.

Copper (Cu): The concentration of copper ranged from a minimum of 0.046 ± 0.002 mg/L (Site 1) to a maximum of 0.07 ± 0.004 mg/L (Site 2) which is below the standard recommended by WHO for fresh surface water. Cu concentrations were not significantly different among the sampling sites at a 95% level ($P > 0.05$).

Lead (Pb): The concentration of lead ranged from a minimum of 0.0187 ± 0.006 mg/L (Site3) to a maximum of 0.025 ± 0.005 mg/L (Site 1). In all sampling sites, Pb concentrations were found to be above the minimum permissible limit set by WHO and below the minimum permissible limit set by EEPA. The increase in Pb concentration in the sampling sites might be due to wastewater from car washes, domestic waste, etc., that is being discharged through small tributaries that pass through the center of the university. Agricultural activities practiced around the university might also contribute to the observed high levels of lead since this metal can occur as impurities in fertilizers and metal-based pesticides and compost and manure. ANOVA analysis showed that among the sampling sites the mean concentration of Pb was not significantly different at 95% ($P < 0.05$).

Cobalt (Co): The average means concentrations of Co was 0.075 ± 0.003 mg/L for S1; 0.05 ± 0.01 mg/L for S2 and 0.044 ± 0.01 mg/L for S3. The concentration of Co recorded for all the sampling sites was higher than the permissible limit endorsed by WHO. The high level of Co might be due to sewage effluents, urban runoff, and agricultural runoffs that enter the sampling sites. The Statistical results from ANOVA at ($P < 0.05$) have shown that there is a significant difference in Co concentration among the sampling sites.

Chromium (Cr): The average means concentration of Cr was 0.075 ± 0.003 mg/L for S1; 0.12 ± 0.01 mg/L for S2 and 0.17 ± 0.013 mg/L for S3. The concentrations of Cr recorded for all the sampling sites were below the provisional discharge limit values of EEPA and above the limit of WHO, 2002. ANOVA analysis at ($P < 0.05$) showed that there is a significant difference in Cr concentration among the sampling sites.

Conclusion: The values of physicochemical parameters such as BOD, COD, TSS, and E.C were found to be higher than the acceptable limits for discharging wastewater into the environment and surrounding surface water bodies. As a result, the wastewater released from Wachamo University has a potential impact on the surrounding environment, human health, and downstream users. Therefore, the University should apply a proper waste management system to treat the effluent generated from its compound to reduce environment pollution and avoid human health risks.

Data Availability: All the data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest: The authors declare that there is no conflict of interest regarding the publication of this paper.

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