Assessment of Nutrients and Heavy Metals in the Groundwater and Surface Water in the Zeber Watershed: The Case of the Bahir - Dar City Waste Disposal Site

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Abstract. Surface water and groundwater have been experiencing increasing risks of contamination in recent years because of the poor management of the immense amounts of waste created by different human activities. Inappropriate dump sites have served for many years as marginal disposal sites for a wide range of wastes, including solid waste, fresh sewage and hazardous waste, in developing nations such as Ethiopia. Physical, anthropogenic and organic procedures continuously interact to degrade the waste. One of the results of these practices is artificially contaminated leachate, which is potentially hazardous waste from disposal sites. If not managed appropriately, dumping sites can contaminate groundwater (through leachates) and surface water (through contaminant transport by flooding and groundwater movement). Along these lines, this study focuses on the spatial and temporal variations in the ground and surface water quality caused by the waste disposal site of Bahir Dar city within the Zeber watershed during the dry and wet seasons. Water testing was performed on 5 samples of surface water and 6 samples of groundwater in each month from the 30th of March (dry season) to the 20th of August (wet season). Water quality parameters, for example, total coliforms, NO_3^-, PO_4^{3-}, Cr, Mn, and Pb concentrations were examined in both ground and surface water. It was discovered that the NO_3^-, Mn and Pb contents were within established limits for both ground and surface water, while the remaining parameters varied depending upon the sampling period. The water quality study results show that spatial and temporal variations have strong impacts on the changes in microbial, heavy metal and nutrient parameters throughout the watershed.

Keywords: Groundwater · Seasonal variation · Waste disposal site · Surface water

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1 Introduction

1.1 A Subsection Sample

Water is the most plentiful asset on earth, yet just 3% is available for human activities, while the remainder is available in the sea as salt water [1]. Water may be accessible in different forms and amounts, yet its utilization for different purposes is the source of its value. Of all the ecological problems that developing nations face, the absence of sufficient and clean water remains the most important issue [2]. When contaminated, groundwater will remain contaminated in the absence of remediation or treatment. Diseases may be spread through water contamination, particularly groundwater contamination, and quickly overwhelm human abilities to control their spread [3]. Wastes of various kinds, for the most part solid waste, make up a significant proportion of dump sites/landfills. Hydrological studies of groundwater show that it flows from areas of higher elevation towards areas of lower elevation. Along these lines, we assessed the degradable materials that make up leachate and taint the groundwater in the study area. Unfortunately, groundwater is not visible and is therefore considered irrelevant; however, it requires substantial consideration. Groundwater is not disconnected from water supplies or streams; it typically becomes surface water through springs and enters waterways, and it is frequently significant for supporting wetlands and their biological systems. The expulsion or impoundment of groundwater can influence the total flow. A decrease in either the nature or the amount of released groundwater can fundamentally impact surface water quality and the fulfillment of water quality goals. Surface water and groundwater are intricately connected with the water cycle, with numerous recurrent patterns. In the event that groundwater becomes contaminated, it is challenging, though certainly feasible, to restore this water. The moderate pace of groundwater flow and the low microbiological movement limit self-filtration. In developing nations, open and inappropriate dumping destinations have served as final removal sites for a wide range of wastes over many years; these wastes include city solid waste, raw sewage and hazardous wastes [4]. Physical, synthetic and natural procedures interact, resulting in breakdown of the waste. One of the side effects of these practices is artificially contaminated leachate, which is possibly unsafe waste from waste removal destinations. If legitimate waste administration is not performed, such dumping sites can contaminate groundwater (as a result of leachates) and surface water (through contaminant transport by flooding, wind and groundwater from open dump sites). The Bahir-Dar city open landfill is one such open dump site and is situated in a location close to human settlements. The people who live close to the removal site (both below and above the point source) utilize contaminated ground and surface water in their everyday activities. This poses a great deal of danger to those communities with respect to water quality. Along these lines, the focal point of this study was to survey and assess the water quality in that watershed, especially close to the waste disposal site, to assess its impact on ground and surface water quality.

2 Methodology

2.1 Descriptions of the Study Area

The Eriamecharia municipal waste disposal site is 5 km from Bahir Dar city, Ethiopia, near the expressway to Addis Ababa and the Tis Abay waterfall. It forms part of the Sebatamit provincial network. According to the Central Statistics Agency of Ethiopia (CSA 2007 G. C), approximately 6,401 people, 3,053 females and 3,348 males, live around the dump site. Its geographical location is as follows: latitude, 11.54; longitude, 37.38; altitude, 1803 m at 3°; and elevation above sea level, 1801 m. The length and width of this removal site are 384 m and 174 m, respectively. This site was not equipped with liners or a leachate sorting system until ten years ago and was not efficiently planned before being utilized for waste removal/dumping. In addition, no environmental impact assessment was performed before this location was established as a waste disposal site. Trucks and other vehicles from various parts of the city collect the waste, carry it to this site and dump it in a disorganized manner. The waste is dumped as-is without isolation. The base amount of solid waste that is generated from the city and dumped at the site is as follows: private waste 12,610 kg/day, business waste 4,202 kg/day, service provider waste 98 kg/day, municipal waste 1,044 kg/day, and overall waste 22,774 kg/day (Source: Solid Waste Portrayal and Evaluation from the Bahir Dar city report, 2007). Currently, the average amount of waste dumped at the site is estimated to be 31,321 kg/day.

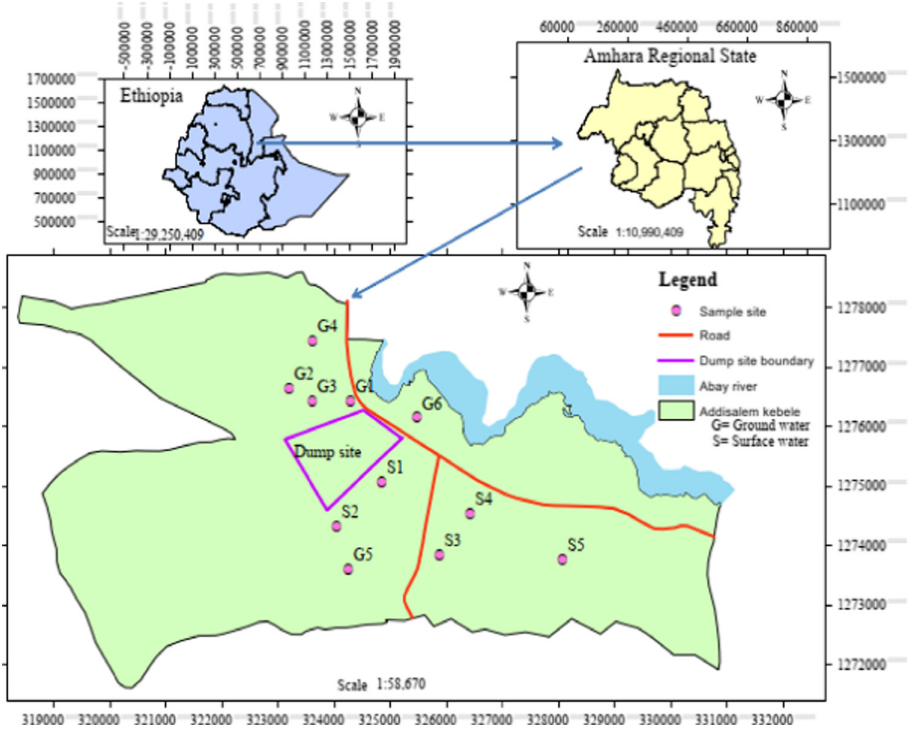

Fig. 1. Topographic map of the study area.

2.2 Sample Collection, Preservation and Laboratory Analyses

Water samples were collected from the selected test areas close to the dump site, which are locally called Abohoy manekia and Tikkurit. The samples were taken to the research Centre for the investigation. The eleven testing sites were selected based on their availability (not being dried throughout the year) and vicinity (distance from the waste disposal site) to contamination sources, for example, accessibility and lodging. A worldwide positioning system device (GPS etrex VISTA HCX) was utilized to identify the actual locations of the study sites, and the sites were geo-referenced to guarantee consistency in the testing sites during the subsequent test periods. The test sites were deliberately chosen to incorporate below and above the waste disposal site, as shown in Fig. 1. Sampling began during the dry season starting in March and proceeded through the wet season in August at all eleven study sites below and above the dump site. Groundwater samples (existing boreholes) were taken from depths of 5–12 m above and below the waste disposal site using borer drills to obtain a 3 L maximum sample with a straightforward core approach that allowed the study of groundwater samples at different borehole depths. To evaluate the water quality, the water samples were kept in 1 L polyethylene plastic containers that had been cleaned with a cleanser that did not contain metals, flushed with deionized water, treated with 10% corrosive nitric acid for 24 h, and finally washed with ultra-pure water. All water samples were stored in a cooler and were transported to the laboratory at [5] approximately the same time. All samples were kept at a consistent temperature of 4 °C to prevent deterioration due to light until the analysis was performed at the research Centre [6]. The total coliform analysis utilized the film channel technique, and the heavy metal (Cr, Pb, and Mn), phosphate (PO_4^{3-}) and nitrate (NO_3^-) contents were determined using a Palintest spectrophotometer (WAGTECH 8000). All analysis procedures were performed according to the Standard Methods for the Examination of Water and Wastewater [7].

Table 1. Types of water source and distance of sampling point from the dump site.

Sample number	Type of water source	Depth (m)	Distance from dump site
1	Shallow well(GSS_1)	8m	87m from dumping site
2	Shallow well (GSS_2)	5m	187m from dump site
3	Shallow well(GSS_3)	10m	229 m from dump site
4	Shallow well(GSS_4)	11	501m from dumping site
5	Spring (GSS_5)		927 from dump site
6	Shallow (GSS_6)	12	908m from dump site
7	Surface(river source,SS_1)	-	317m from dumping site
8	Surface(river source SS_2)	-	115m from dumping site
9	Surface(river source SS_3)	-	3km from dumping site
10	Surface(river source SS_4)	-	3 km from dumping site
11	Surface(river source SS_5)	-	6km from dumping site

3 Results and Discussions

3.1 Spatial and Temporal Variations in the Nutrients and Microbiological Parameters of Surface Water

The results for the spatial and temporal variation in surface water concentrations of nutrients and microbiological parameters measured are presented in Table 2.

Table 2. Spatial and temporal variations in the concentrations of nutrients and microbiological parameters of surface water in the Zeber watershed.

Sampling sites (SS)	NO_3^- (Mg/L)		PO_4^{3-} (Mg/L)		TC (CFU/100 ml)	
	Dry Season	Wet Season	Dry season	Wet Season	Dry Season	Wet Season
SS_1	0.303 ±0.23	0.42 ±0.11	0.153 ±0.031	0.253 ±0.055	11±2	19.33 ±3.055
SS_2	0.0664 ±0.0023	0.903 ±0.083	0.13 ±0.02	0.6233 ±0.051	22±4	34.333 ±3.512
SS_3	0.0593 ±0.0021	0.7633 ±0.106	0.21333 ±0.0153	0.27 ±0.0361	16 ±2.65	20.667 ±3.512
SS_4	0.225 ±0.11	0.607 ±0.021	0.245±0.033	0.363 ±0.050	21.67 ±2.082	30.66 ±3.512
SS_5	0.050 ±0.002	0.316 ±0.056	0.127 ±0.012	0.58 ±0.046	13.67 ±2.082	24 ±3.61

Dynamics of nitrate in the surface water: The nitrate levels in the surface water samples varied from 0.050 ± 0.002 to 0.303 ± 0.23 mg/L with a mean value of 0.141 ± 0.068 mg/L. In the wet season, the levels ranged from 0.316 ± 0.056 to 0.903 ± 0.083 mg/L (Table 2) with a mean value of 0.601 ± 0.074 mg/L. In the two seasons, the levels of nitrate at all testing sites were well below the EPA limit of 10 mg/L. This is most likely because of the absence of DO in the water samples; the lower levels of nitrate may be due to the higher levels of ammonia as a result of the disintegration of nutrient waste and different sources of protein. As indicated by Weiner et al. (2003), the sources of nitrates in water include rotting plant or animal materials, horticultural compost, excrement, human or animal waste, and household sewage. The most notable nitrate levels were observed at SS2 (0.903 ± .083 mg/L), SS3 (0.7633 ± 0.106 mg/L) and SS4 (0.607 ± 0.021 mg/L) during the wet season because of evaporation. $NO3^-$ leaches from several sources, for example, rotting plant and animal materials, farm compost and residential sewage, excessive use of manure, and high levels of natural waste originating from point and non-point sources. The lowest levels of nitrate in the water samples of the study region were recorded during the dry

season at SS2 (0.0664 ± 0.0023 mg/L), SS3 (0.0593 ± 0.0021 mg/L) and SS6 (0.050 ± 0.002 mg/L); these values were much lower than those measured in the wet season. As indicated by the WHO water quality threshold of 10 mg/L, the water in the study region should be prevented from contaminating the surrounding water bodies with nitrate. This contamination could be expected due to nitrifying microscopic organisms fixing the free nitrogen in the air into nitrate, making it usable for photosynthetic plants in the study zone. Excessive levels of nitrate can negatively impact water quality and can accelerate eutrophication.

Dynamics of phosphate in the surface water: The levels of phosphate, measured as PO43-, in all samples in the dry season ranged from 0.127 ± 0.012 to 0.245 ± 0.033 mg/L with a mean level of 0.174 ± 0.023 mg/L. In the wet season, the level of phosphate ranged from 0.253 ± 0.055 to 0.6233 ± 0.051 mg/L (Table 2), with a mean value of 0.42 ± 0.048 mg/L. The research facility results demonstrated that PO43- fixation in all samples of surface water in the dry and wet seasons was frequently much higher than the recommended threshold of 0.1 mg/L for drinking water set by the EPA/WHO. This is likely due to the waste disposal site, which contains diverse forms of metropolitan waste such as human waste, shampoos, food waste and beautifying agents. This is in accordance with a study conducted by Tjandraatmadja [8] who found that phosphate levels increase because of an increase in the use of phosphate-generating products, for example, cleaning products (cleansers), beautifying agents, relaxer shampoos, food items, wastewater with high phosphate levels from the surrounding communities, spill-over containing soil-bound phosphates, yard waste, overflow from animal feedlots, storm water, and other sources including human waste (faeces and urine). High levels of phosphate indicate the severity of contamination and are, to a great extent, responsible for eutrophic conditions. Phosphate is fundamental for the development of vegetation and other natural living beings. Tjandraatmadja [8], found that unlawful methods of waste disposal into a zone used for surfing brought about excessive algae growth, eutrophication and oxygen consumption in water bodies. In light of this study, the Bahir Dar city waste disposal site is a case study for waste disposal sites, and it represents the seriousness of this issue. Despite the fact that phosphate levels were very high compared with the baseline phosphate levels, the highest levels of phosphate were found in the wet season at test sites SS2, SS5 and SS4; the lowest levels were found in the dry season at test sites SS5, SS2, and SS1 (Table 2). Overall, phosphate fixation was highest at SS2 during the rainy season (0.6233 ± 0.051 mg/L) followed by the highest value recorded during the dry season (0.245 ± 0.033 mg/L) at SS4. This could be ascribed to the increased flooding during the wet season at the dump site (household waste) and the upstream rural contributions to the water test sites, especially those containing cleaning products and compost overflow from dump locales and other sources. The low levels recorded in the dry season may have been caused by evaporation. The water sources in the study region are likely not safe for drinking and residential purposes due to the phosphate levels. This is in accordance with the findings of a few specialists. For instance, Akpan [9] demonstrated that phosphate fixation in water was higher than the level recommended by the

World Health Organization (WHO). Abundant phosphate in water promotes algal blooms and the growth of toxic algae that harm the neurological system and lead to oxygen consumption in the water [9]. From the ANOVA results, there was a significant difference in phosphate fixation between the wet season and the dry season. This indicates that the season is one of the principal factors determining the level of phosphate in the water.

Total Coliform in the Surface Water: The motivation behind measuring the total coliform content in the water bodies was to assess the quantity of coliform bacteria in the water samples as an indication of the extent of natural contamination. The total coliform content of the surface water samples in the dry season ranged from 11 ± 2 to 22 ± 4 CFU/100 ml, while in the wet season, it ranged from 19.33 ± 3.055 to 34.333 ± 3.512 CFU/100 ml. Table 1 above shows that the highest level of total coliforms was measured at SS2 (34.333 ± 3.512 CFU/100 ml) in the wet season, while SS1 (19.33 ± 3.055 CFU/100 ml) recorded the lowest total coliforms in the same season. During the dry season, the highest level of total coliforms was recorded at SS2 (22 ± 4 CFU/100 ml), while SS1 (11 ± 2 CFU/100 ml) had the lowest total coliform count in the same season. These results show that in the study area, total coliform levels were low in the dry season and high in the wet season. This is because of the movement of effluent from pit toilets, residential sewage, city waste and rotting natural materials from the waste disposal site to the surface water test sites. In addition to the increased water temperature and the decrease in decomposition, oxygen may contribute to critical levels of total coliform pollution in water bodies in the study area [10]. As indicated by the WHO allowable limit, the total coliform levels recorded in the two seasons in the study area were much higher than the recommended value. Consequently, based on this parameter, the water is unacceptable for use. The high total coliform value during the wet season (at the same sampling point as in the dry season) was in accordance with Venkatesharaju [11] who researched the physicochemical and bacteriological parameters of water at Cauvery College in Karnataka. Their study revealed that the wet season had higher coliform values than the dry season. This high coliform level during the wet season was attributed to the release of residential waste containing faecal matter to the water body and open defecation at the edges of the stream bank. Overall, the ANOVA results from SPSS show that the total coliform level was temporally critical but not spatially critical during the study time frame. This implies that season has a more important role than location because of ecological conditions such as precipitation, moisture, and temperature.

3.2 Spatial and Temporal Variations in the Levels of Heavy Metals in Surface Water

The spatial and temporal concentrations of heavy metals in surface water estimated at each of the five test sites throughout the study period are presented in Table 3.

Table 3. Spatial and temporal variation of heavy metals in surface water.

Sampling sites (SS)	Cr (mg/L)		Mn (mg/L)		Pb (mg/L)	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
SS_1	0.0066 ±0.0001	0.063 ±0.0086	0.0046 ±0.0034	0.023 ±0.0057	0.0017 ±0.000252	0.009133 ±0.0112
SS_2	0.0677 ±0.0015	0.29 ±0.053	0.0029 ±0.0037	0.00933 ±0.0112	0.002233 ±0.00038	0.00293 ±0.000252
SS_3	0.0241 ±0.0311	0.04 ±0.001	0.0026 ±0.0034	0.0072 ±0.0094	0.001967 ±0.0032	0.00267 ±0.00031
SS_4	0.064 ±0.00153	0.2467 ±0.057	0.00202 ±0.0026	0.0053 ±0.0067	0.002067 ±0.00032	0.0074 ±0.00922
SS_5	0.056 ±0.0034	0.25 ±0.0361	0.00251 ±0.0033	0.0133 ±0.0171	0.00167 ±0.000322	0.00467 ±0.0055

Manganese: - The concentration of manganese in all samples of surface water during the dry season ranged from 0.00202 ± 0.0026 mg/L to 0.0029 ± 0. 0037 mg/L (Table 2) with a mean value of 0.00291 ± 0.00326 mg/L, while in the wet season, it ranged from 0.0053 ± 0. 0067 to 0.023 ± 0.0057 mg/L with a mean value of 0.012 ± 0.01014 mg/L. Based on the results in both the dry and wet seasons, the levels of manganese were well below the EPA/WHO/January 2004 standard value (0.5 mg/L).

Chromium: - From the study, levels of chromium in all samples of surface water during the dry season ranged from 0.0066 ± 0.0001 to 0.068 ± 0.0015 mg/L (Table 3) with a mean value of 0.044 ± 0.18 mg/L. In the wet season, the levels of chromium ranged from 0.04 ± 0.001 to 0.29 ± 0.053 mg/L with a mean value of 0.178 ± 0.0311 mg/L. The most extreme levels of chromium during the dry season were recorded at SS2, SS4 and SS5, with the lowest level at SS1. During the wet season, nearly all qualities increased to above the WHO (January 2004) standard value (0.05 mg/L). Chromium may have reached the sampling sites through the movement of leachate because of precipitation at the dump site. Therefore, the water in the study area should not be used by residents due to its chromium levels, since chromium is one of the most lethal metals due to its influence on the nervous system and effects on the brain and kidneys. Infants and children who drink water containing chromium levels higher than the recommended level could encounter delays in their physical or mental advancement. Children can experience shortfalls in their capacity to focus and learn, while adults who drink this water could conceivably develop kidney issues or hypertension [12].

Lead: - The concentrations of lead in all samples of surface water during the dry season ranged from 0.00167 ± 0.000322 mg/L to 0.002233 ± 0.00038 mg/L (Table 3) with a mean value of 0.00192 ± 0.00032 mg/L, while in the wet season, it ranged from 0.00267 ± 0.00031 to 0.009133 ± 0.0112 mg/L with a mean value of

0.0054 ± 0.0053 mg/L. As is clear from the results in both the dry and wet seasons, the concentrations of lead were lower than the EPA/WHO/January 2004 standard value (0.01 mg/L). This may be because of the lack of disposal of lead-corrosive batteries, paint, fuel and colourants at the waste disposal site that could flow to the surface water sampling sites. It appears that the waste disposal site did not contribute fundamentally to increasing lead levels over the standard values. Despite the fact that all values were low, the concentration of lead that was measured during the study time frame fluctuated from site to site and season to season. The most extreme concentrations of lead were recorded at SS1, SS4 and SS5, with the lowest level at SS3 during the wet season. During the dry season, the highest levels were recorded at SS2 and SS4, with the lowest level at SS5. At the beginning of the period, the most extreme mean value, 0.0054 ± 0.0053 mg/L, was obtained in the wet season, though the lowest value, 0.00192 ± 0.00032 mg/L, was obtained in the dry season due to the impact of precipitation forcing the contamination to spill out of its source into the surface water test sites.

3.3 Spatial and Temporal Variation in the Estimations of Nutrients and Microbiological Parameters of Groundwater Quality

The results for the spatial and temporal variation in groundwater concentrations of nutrients and microbiological parameters measured are presented in Table 4.

Table 4. Spatial and Temporal Variations in the Nutrients and Microbiological Parameters of Groundwater.

Sampling sites	NO_3^- (mg/L)		PO_4^{3-}(mg/L)		TC (CFU/100ml)	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
SS1	0.071±0.0011	0.53±0.056	0.0058±0.003	0.0018±0.001	8.33±0.1.53	13±3
SS2	0.72±0.023	0.66±0.053	0.0088±0.0029	0.031±0.023	6.33±1.53	13.67±5.132
SS3	0.09±0.003	0.94±0.056	0.048±0.0023	0.0072±0.005	7.33±3.51	18.33±4.51
SS4	0.73±0.01	0.51±0.02	0.039±0.003	0.05±0.0075	5±1	16±1
SS5	0.073±0.0021	0.52±0.16	0.064±0.0042	0.264±0.0.34	11.67±2.52	23±6
SS6	0.08±0.0021	0.55±0.06	0.098±0.001	0.262±0.87	9±2	20±4.583

Dynamics of nitrate in groundwater: From the investigation, the levels of nitrate during the dry season ranged between 0.071 ± 0.0011 and 0.08 ± 0.0021 mg/L with a mean value of 0.34 ± 0.006 mg/L, while in the wet season, it ranged from 0.51 ± 0.02 to 0.94 ± 0.056 mg/L with a mean value of 0.62 ± 0.07 mg/L (Fig. 2). Figure 2 shows that all values in the dry and wet seasons were well lower than the WHO standard value of 50 mg/L nitrate for groundwater. This is likely because of the total absence of DO in the wastewater; the low level of nitrate is the result of

ammonification from the decomposition of food waste and different sources of protein. Generally, the factors that influence the occurrence of nitrate in groundwater boreholes are subsurface mud focal points and land use practices. The findings of low levels of nitrate (below the WHO standard) during the assessment time period were similar to those of Akale, Moges et al. and Tilahun [13], who evaluated nitrate in wells and springs in northern Ethiopian regions and discovered values lower than the WHO standard threshold throughout the study time frame. Despite the fact that all values were below this threshold, the mean concentrations of nitrate obtained during the wet season were higher than the concentrations in the dry season (Fig. 2).

Dynamics of Nitrate in Groundwater: The high levels of nitrate in the wet season during the study time frame were similar to those in the study of Akale and Adugnaw [14] who examined groundwater quality in an upland farming watershed in sub-humid Ethiopian regions and discovered higher levels of nitrate during the wet season than during the dry season. The high nitrate level in the wet season may have been due to an expanded flush of nitrate-containing substances (blended sources, for example, rotting plant or animal materials, farming compost, fertilizer, manure, human or animal wastes and household sewage) from the waste disposal site, and storm events may have brought nitrate from the site to the surrounding areas; the high nitrate level may also have been due to freshwater inflow and surface run-off during the wet season [15]. Another conceivable method for nitrate removal is through the oxidation of the alkaline type of nitrogen into nitrite [16]. For the most part, during the wet season, groundwater is refreshed by precipitation due to permeation, prompting a general increase in the water level. This makes groundwater exceptionally vulnerable to contamination and overflow activities, as the components in soils and rocks are readily discharged into the water. The fundamental source of nitrate in these groundwater samples could be the utilization of compound composts on ranches that generate releases and overflow from animal feedlots, which have been distinguished as some of the primary drivers of nitrate in groundwater. In addition, the ill-advised disposal of human and animal wastes on open lands filters lingering nitrate, resulting in high nitrate fixation in groundwater in the wet season. In most cases, the use of synthetic composts, the ill-advised disposal of human and animal waste and the impact of seasons are the principal factors influencing the sources of nitrogen that is converted to nitrate in the soil. The lowest mean value was recorded during the dry season due to the low freshwater inflow and high salinity [17] and [18]. In terms of spatial variance, the highest value was obtained at ground water sampling site four (GSS4) and the lowest was obtained at ground water sampling site one (GSS1) during the dry season. In the wet season, the highest value occurred at GSS3, and the lowest occurred at GSS1 (Fig. 2). The high values may have been caused by rotting plants, fertilizer, manure and spill over since ground water sampling site three (GSS3) and ground water sampling site four (GSS4) are located near grooming areas and plant nurseries. For the low values, the opposite is true. Based on the ANOVA results, there was no significant difference between the test sites or between the seasons that could have brought the nitrate levels over the WHO threshold.

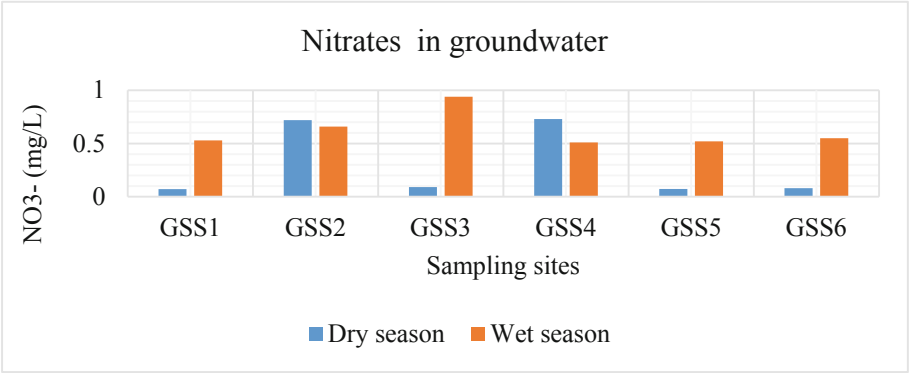

Fig. 2. Seasonal variation in the nitrate level in groundwater in the study area.

Dynamics of phosphate in groundwater: The level of phosphate in the groundwater samples ranged from 0.0088 ± 0.0029 to 0.098 ± 0.001 mg/L in the dry season and 0.002 ± 0.001 to 0.264 ± 0.0.34 mg/L in the wet season (Fig. 3). The findings of the study show that higher levels of phosphate were found during the wet season than in the dry seasons in all the groundwater samples except GSS3 (Fig. 3). This difference can be attributed to high moisture levels in the soil of the waste disposal site, which contains human waste, relaxer shampoos, food waste and beautifying agents that can leach phosphate into the groundwater. For the most part, the level of phosphate during the wet season may increase because of the contribution of phosphates from external sources, ill-advised solid waste disposal, overflow from the excessive utilization of mixed manures and the decay of rocks and minerals that contain phosphates. Phosphates are generally very well adsorbed into the soil and can be transported into the surrounding catchments. The water bodies receive runoff from rainstorms, explaining the high phosphate levels in nearby water bodies. The lowest level of phosphate was measured during the dry season, which may have occurred because of the low solvency of local phosphate minerals and the capacity of soils to retain phosphate. This is in accordance with the findings of Gadhia and Ansari [19], who studied regular variations in the physical attributes of an estuary in the Hazira industrial region and measured a higher level of phosphate during the wet season than during the dry season. With respect to the spatial variation, the most noteworthy concentrations of phosphate were recorded at ground water sampling site five (GSS5) followed by ground water sampling site six (GSS6) during the wet season, with the lowest level measured at GSS1. In the dry season, the highest level was measured at GSS6, and the lowest at GSS2 (Fig. 3). This was because of the location (being below and above the point source) of the boreholes at the chosen waste disposal site. According to the results (Fig. 3), aside from GSS5 and GSS6, the concentration of PO43- in both the dry and wet seasons was below the WHO limit (PO43- = 0.1 mg/L). In accordance with this, the statistical (ANOVA) result demonstrates that there was no significant difference in the mean phosphate levels among test sites or seasons during the study time frame ($p < 0.05$).

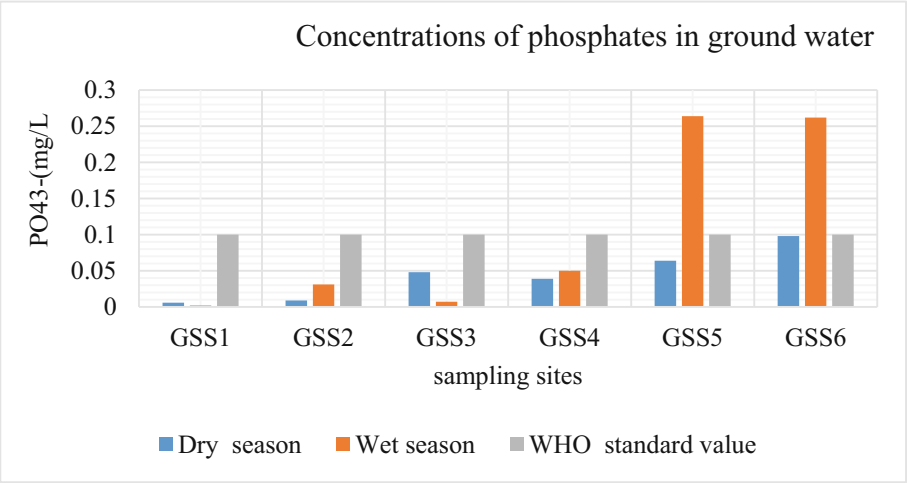

Fig. 3. Seasonal variation in phosphate in the groundwater in the study area.

Total Coliforms: The results of the bacteriological study of borehole water samples showed that the total coliform level during the dry season ranged from 5 ± 1 to 11.67 ± 2.52 CFU/100 ml with a mean value of 7.9 ± 2.01 CFU/100 ml, while in the wet season, total coliforms ranged from 13 ± 3 to 23 ± 6 CFU/100 ml, with a mean value of 17.3 ± 4.04 CFU/100 ml (Fig. 4). This result shows that the bacterial values exceeded the WHO threshold of 0 CFU/100 ml for drinking purposes. This indicates that the groundwater samples were contaminated with coliform bacteria. This is likely due to waste, especially human waste that is shipped from Bahir Dar city and released directly to the open landfill (at the open waste disposal site). It can thus be construed that the samples were, for the most part, contaminated by the channels flowing out from the waste site that release their substances directly, without any land barriers. The mean value of total coliforms measured during the wet season was higher than that measured during the dry season. This may be because the released human waste or faecal matter was flushed/washed away by precipitation from its source to the various water bodies. At that point during its flow, the waste joins surface waters and open wells and also drains into groundwater through permeation and invasion. The uncovered soil is contaminated with faeces as a result of rainstorms and drainage into open wells due to surface spill over, and this could likewise have been responsible for the higher bacterial load during the wet season than during the dry season. The test sites that are closest downstream of the disposal site, GSS5 and GSS6, showed increasing levels of total coliform. The test sites situated across the dump site were suddenly contaminated with coliform bacteria. This may have been because of excrement and different waste from anthropogenic sources (open field defecation along ditches by people and the different animals that eat near the groundwater sites) located in brambles near the drilled holes. This area was eventually flushed with water as spill over; the waste then spilled into the groundwater and was mixed in the open wells and spring water by means of surface streams. The highest values of total coliform among the six groundwater samples were found at GSS5,

GSS6, GSS1 and GSS3, with the lowest value at GSS4 during the dry season. In the wet season, the highest levels were measured at GSS5, GSS6, GSS3 and GSS4 with the lowest level measured at GSS1. The mean total coliform values in the water at the six testing sites in the study area during the dry and wet seasons are shown in Fig. 4.

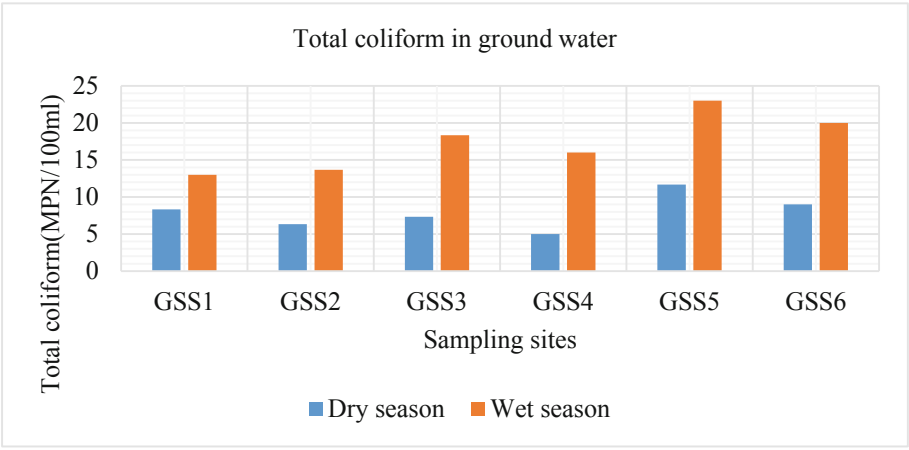

Fig. 4. Seasonal variation in total coliforms in groundwater in the study area.

3.4 Concentrations of Heavy Metals in Groundwater

Table 5. Spatial and temporal variation of heavy metals in Groundwater.

Sampling sites	Cr (mg/L		Mn (mg/L		Pb(mg/L)	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
SS1	0.0225 ±0.017	0.039 ±0.0285	0.0018 ±0.00053	0.034 ±0.0047	0.00051 ±0.0007	0.00073 ±0.001
SS2	0.011 ±0.0146	0.0203 ±0.026	0.0024 ±0.0001	0.036 ±0.0056	0.00098 ±0.0007	0.00088 ±0.0012
SS3	0.0164 ±0.0124	0.0242 ±0.0174	0.00224 ±0.0017	0.043 ±0.00473	0.00019 ±0.0001	0.00024 ±0.00018
SS4	0.0056 ±0.00021	0.0063 ±0.00082	0.00144 ±0.0019	0.0183 ±0.0042	0.0008 ±0.00061	0.0019 ±0.0009
SS5	0.055 ±0.0049	0.064 ±0.004	0.00196 ±0.00255	0.0166 ±0.023	0.0014 ±0.002	0.00203 ±0.0032
SS6	0.032 ±0.001	0.046 ±0.00551	0.0025 ±0.0032	0.00267 ±0.00065	0.0012 ±0.0015	0.0018 ±0.0026

Chromium: The findings of the study demonstrate that the chromium concentrations of the groundwater samples ranged from 0.0056 ± 0.00021 mg/L to 0.055 ± 0.0049 mg/L during the dry season with a mean value of 0.024 ± 0.0083 mg/L (Fig. 5). However, during the wet season, the concentrations of chromium ranged from 0.0063 ± 0.00082 mg/L to 0.064 ± 0.004 mg/L with a mean value of 0.033 ± 0.014 mg/L. The measured values show that the concentrations of chromium throughout the study time frame were lower than the WHO admissible limit of 0.05 mg/L for both the dry and wet seasons, with the exception of GSS5 (Fig. 5). The reason for the slight increase at GSS5 was because the fluid waste moving from the dump site passed through the channels that were closer to this borehole sample than to the others. Consequently, there was a higher likelihood of waste draining into this borehole than the other boreholes. This has, in accordance with the possibility of the separation by depth of boreholes from the source of leachate, a stronger effect on the degree of contamination of groundwater. The groundwater samples close to the dump site contained a higher number of particles and cations than those far from the dump site, and the shallow wells in the vicinity of the waste dumping site had higher concentrations of particles, cations, and organic compounds than those farther away from the dump site [20]. Overall, the highest and lowest values were observed at GSS5 and GSS4, respectively, in both the dry and wet seasons because of their location and distance from the waste disposal site. From the ANOVA results, there was a potential significant difference among the testing sites but not between the seasons.

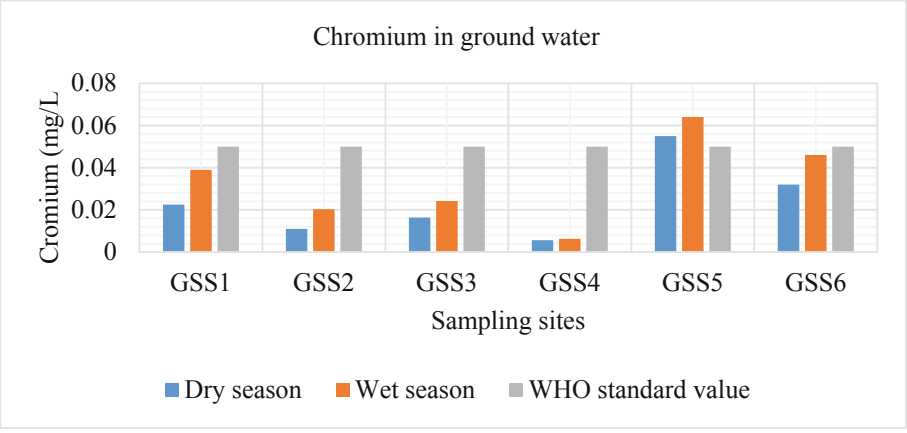

Fig. 5. Seasonal variation in the chromium concentration of groundwater in the study area.

Manganese: As Fig. 6 shows, the concentrations of manganese ranged from 0.0018 ± 0.00053 mg/L at GSS1 and 0.0025 ± 0.0032 mg/L at GSS6 with a mean value of 0.00205 ± 0.0017 mg/L in the dry season and from 0.0166 ± 0.023 mg/L at GSS5 to 0.043 ± 0.00473 mg/L at GSS3 with a mean value of 0.02499 ± 0.0071 mg/L in the wet season. The results (Fig. 6) show that the concentrations of manganese in nearly all groundwater samples were considerably lower than the WHO

allowable level of 0.5 mg/L. This implies that the investigated groundwater samples acquired from the region of the dump site did not obviously indicate that the water quality was influenced by manganese leached from the dump site. Overall, the slightly higher values of heavy metals measured during the wet season (Fig. 6) firmly indicate the impact of precipitation on leachate movement to the groundwater test sites. Another reason for the low values of manganese throughout the study region may have been the absence of natural soils and the stratigraphy of the soil at the selected waste disposal site, which are responsible for the maintenance and assimilation of manganese. Overall, manganese is normally found in groundwater, can vary occasionally in concentration, and changes with the depth and purpose of the well in addition to the geography of the region. Manganese in groundwater is likewise normal in zones where the groundwater flow is moderate and in regions where groundwater is contaminated with natural contaminants. The harmful impacts of manganese intake by humans include neurotoxicity causing ataxia, motor difficulties, anxiety, dementia and autonomic conditions such as Parkinson's disease.

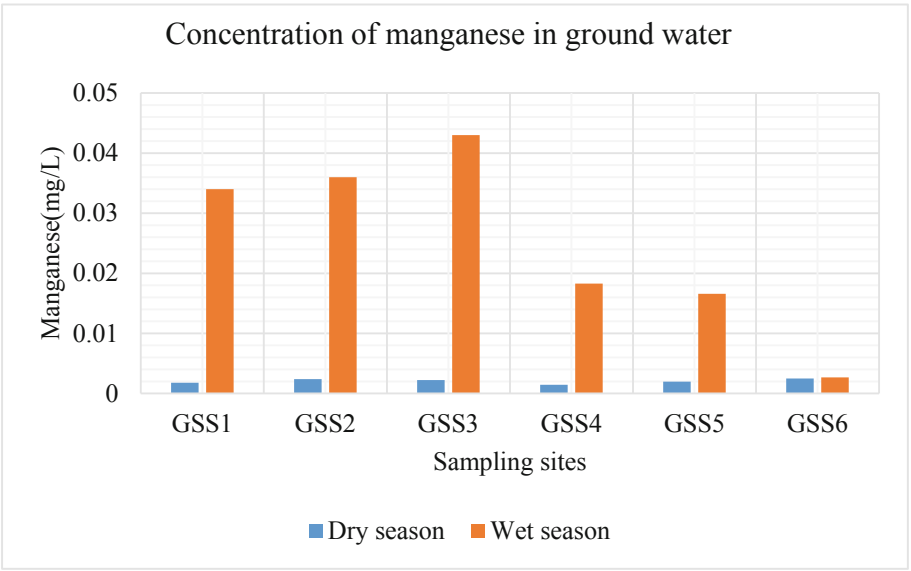

Fig. 6. Seasonal variation in manganese concentrations in groundwater in the study area.

Lead: The levels of lead in the study region ranged from 0.00019 ± 0.0001 to 0.014 ± 0.002 mg/L with a mean value of 0.004 ± 0.002 mg/L in the dry season period, while in the wet season, the levels ranged from 0.00024 ± 0.00018 to 0.0203 ± 0.0032 mg/L with a mean value of 0.0008 ± 0.0002 mg/L (Fig. 6). From Fig. 6, the profile of each study site throughout the study region shows that the mean values of lead in both the wet and dry seasons were lower than the WHO standard limit of 0.01 mg/L. This could be because of the absence of critical garage and painting activities in the community close to the study area or because solid waste, for example,

scrap metal, batteries and electronic waste found at the waste disposal site, which are sources of heavy metals, did not contribute substantially to the lead levels. During the wet season, the levels of lead did not increase, similar to those of Cr and Mn, which may have been because of the extremely low penetration of lead in spring water. This is in accordance with the suggestion of Ohwoghere-Asuma [21] that the extremely low concentrations of heavy metals during the wet season recorded at the waste disposal site indicate the roles played by the occurrence of natural soils and clayey soils below the site. Heavy metals will, in general, be fixed in the waste or waste-stone interface because of redox-controlled responses. These results suggest that the groundwater is not contaminated with lead. Water soaks through the layers of solid waste at the waste removal site. The compounds and the organic and physical procedures cause hazardous synthetic substances from different waste materials to form a dangerous leachate. The risk level of the toxins depends upon the soil type and porosity, the permeability and geophysical attributes of the subsurface, the water table depth and the flow of groundwater.

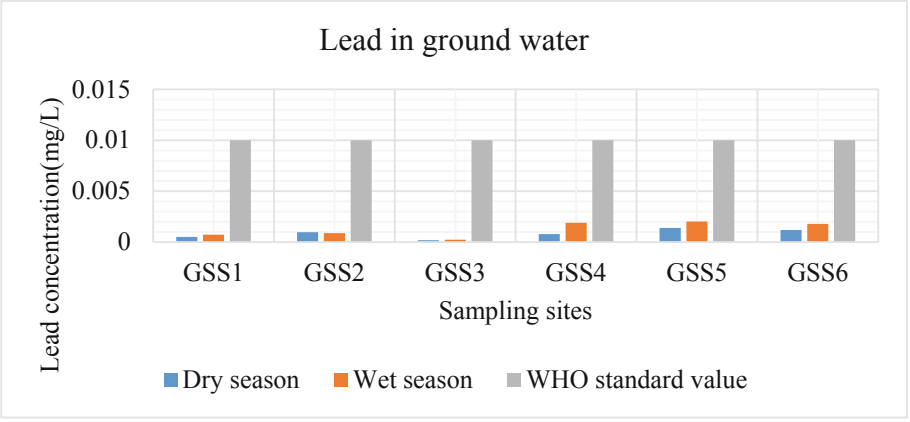

Fig. 7. Seasonal variation in the lead concentration of groundwater in the study area.

4 A Comparison of the Effect of the Open Dump Site on Surface Water and Groundwater Quality in the Zeber Watershed

A general water quality evaluation (ground and surface water) of the Zeber watershed was performed. The results are presented in Fig. 7. As shown in Fig. 7, the average standardized values of the surface water quality parameters were higher than the average standardized values of the groundwater quality parameters. Along these lines, it may be possible to state that the surface water quality was more impacted by the dumping site leachate than the groundwater quality. For most study sites, this was observed through the parameter's phosphate and chromium. Surface water was more influenced than groundwater because surface water is more readily exposed to toxins

released by anthropogenic activity. Each anthropogenic activity takes place at the surface, and consequently, its impacts first influence the surface water. Groundwater is less susceptible to unexpected contamination than surface water given that the soil and rock screen out most of the toxins through groundwater flow. This does not mean that groundwater is safe from tainting, since readily soluble synthetic compounds represent a strong potential to contaminate groundwater. This is similar to the findings of Trivedi, Bajpai, and Thareja, 2008, who discovered that surface water was more strongly influenced than groundwater by outside impact.

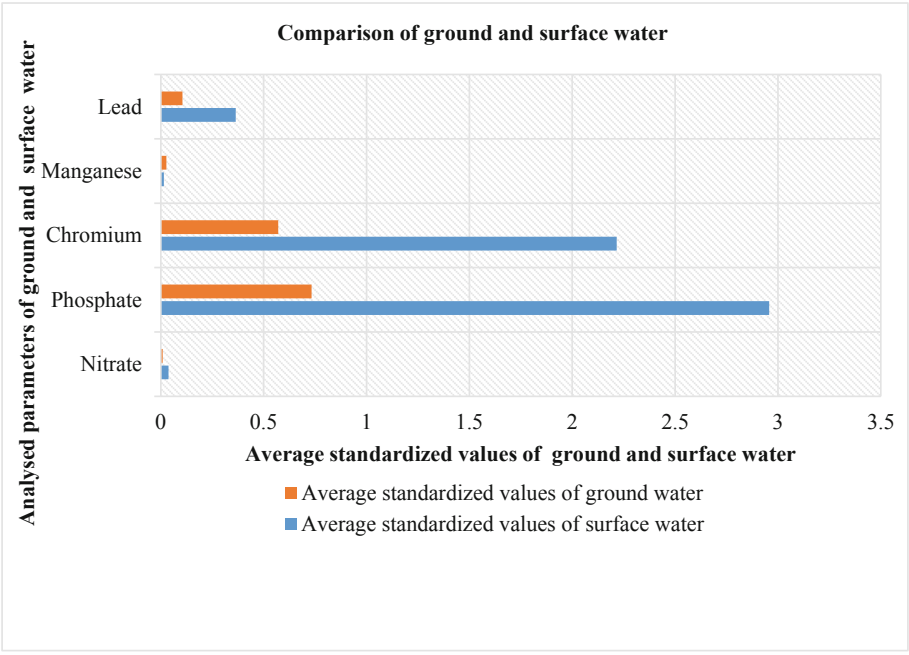

Fig. 8. Comparisons of the effect of the dump site on surface and groundwater quality.

5 Conclusion

The global and spatial fluctuations in the ground and surface water characteristics of the Zeber watershed were evaluated in terms of the WHO water quality parameters. The study of the concentrations of heavy metals and nutrients showed that NO3-, Mn and Pb in both ground and surface water were within the limits during the study period, while the remaining characteristics changed with the seasons.

The findings of the study showed that the sampling sites downstream of the dump site were more strongly influenced by the dump site than the sampling sites upstream of the dump site.

The total coliform levels measured were much higher than the limits for drinking water at all sampling sites. This suggests the importance of more careful consideration of household pollution, natural sanitation control and awareness of water pollution

since the open waste disposal site and the practice of open defecation have greatly affected the watershed of the study zone.

The results of the statistical analysis (one-way ANOVA) performed on the surface water Cr, Mn, Pb, nitrate, phosphate and total coliform data suggest that all measured.

parameters essentially shifted between the seasons during the study period (P-value < 0.05).

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