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Assessment of Selected Heavy Metals in Water and Sediment along Wami River, Tanzania

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ABSTRACT

The study was conducted to assess the heavy metal pollution in water and sediments of Wami River, Tanzania. A total of 60 water samples and sediment were collected from 15 random selected sampling points in three River sections; upstream, midstream, and downstream. All the samples were taken using standard procedures and analyzed using ASS at Ardhi University Laboratory, Tanzania for selected seven heavy metals including Pb, Zn, Cr, Cd, Ni, Co and Hg. The findings show average concentrations of studied metals in water followed the decreasing order of: Co >Pb >Zn > Ni. The mean concentration of Pb in water for dry season and rainy season observed to be 0.22 ± 0.26 mg/L and 0.17± 0.24 mg/L respectively, which was much higher than the WHO standard level (0.05 mg/L) for drinking water, while the average concentration of Zn was observed 0.10 ± 0.14 mg/L and 0.08 ± 0.13 mg/L during dry and rainy season respectively. The minimum and maximum values were found to be 0.37 and 0.41 mg/L respectively. Environmental assessment conducted by three pollution Indices for sediment; Contamination Factor (CF), Index of Geo-accumulation (Igeo) and Pollution Load Index (PLI). The pollution indices confirmed that Wami river sediment was not contaminated with these elements. Further, the study recommends for the future systematic monitoring plans to predict and prevent any potential heavy metal loading and their effects to river water and human being.

Keywords: *Heavy Metals; Pollution Indices; Water; Sediment; Wami River*

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INTRODUCTION

Freshwater comes from rivers, lakes and subsurface aquifers is the main source available for human consumption (Mero, 2011).Unfortunately, these sources account for only one percent of all water on the earth that six billion people worldwide depend on for supply and hence alarming for the water shortages (Hu, et al., 2017). Although provision of safe drinking water is a basic human right the same as for clean air, in most of developing countries in the African and Asian countries, safe drinking water is not easily available (Weiss et al., 2016).

Water shortage is one among challenges encountered the demand of drinking water supply. Poor water quality is another challenge, resulted by contamination from different sources which impact the health and economic status of the consumers as well as biodiversity (Guo et al., 2010). Different sources of pollution have been detected and reported previously as a result of anthropogenic activities and natural processes. Urbanization, industrialization, transportation, indiscriminate use of fertilizers, improper disposals of sewage and solid wastes material containing toxic chemicals, precipitation inputs erosion and weathering are among the sources of water pollution (FAO, 2017). When using chemical fertilizers and other soil inputs on agriculture activities, pollutants are partly filtered by the soils, sediments and the plants but some of the pollutants eventually enter the water sources (Paul, 2017).

Heavy metals are toxic when present at higher concentrations than the required amount for normal growth of living organisms including human (Jiang et al., 2013). Their existence in aquatic environments has led to serious concerns about their influence on plant and animal life, and thus, cause risk contamination of the soil and subsequently to the food chain (Paul, 2017). The analysis of heavy metals in sediments and water is an important factor for environmental health since they are capable of being up taken by plants, fish and reaching human being through food chain (Briffa et al., 2020). Presence of heavy metals in fresh waters can also come from natural sources which is difficult to monitor such as weathering of rocks that resulting into geochemical cycling of heavy metal in these ecosystems (Ali, et al., 2016). Heavy metals are generally not removable even after the treatment. Lack for mechanisms and sensitive tools to detect and monitor water quality in developing countries resulting into exposure to heavy metal poisoning (Anyanwu et al., 2018).

In Tanzania’s major catchments, similar sources of pollution have been reported to deteriorate water quality. It was reported that there is an increased demand for water and water scarcity in the Wami-Ruvu sub-basin (Kiwango et al., 2015; URT, 2014). The scarcity is mainly experienced during the dry season in the sub-basin due to the construction of Mindu Dam (Nobert & Skinner, 2016). However, heavy metals are the threatening pollutants in this basin and along river environments which are coming from poor management of industrial wastes at upstream points and lack of continuous monitoring plans for water quality (Sawe et al., 2021a). The problem regarding water quality caused by the geographical upstream areas accelerates the continuous conflicts with downstream users and quality uncertainty to water users (Sawe et al., 2021b).

Significant number of studies conducted regarding hydrological situation and water quality in the sub-basin despite the vast anthropogenic influences within the study region. However, the quantity of heavy metal in water as well as sediments within the Wami river has not previously been attempted, hence not known. Considering these factors, an evaluation of the abundance of heavy metals in this river system would be beneficial for future management of the system. Hence the purpose of this study is to assess and quantify the pollution status by analyzing the selected seven heavy metals including Hg, Zn, Pb, Cd, Ni, Cr and Co from water and sediment samples of Wami river compared by seasons and space boundaries.

MATERIALS AND METHODS

Description of study area

Wami river is one among two main river systems of Wami-Ruvu water resource basin that located between 5°–7°S and 36°–39°E and covers an area of 72.930 km^2 in Tanzania (Yanda & Munishi, 2007). Wami River has its source specified in the Kaguru Mountains and it flows in a south-east direction discharging into the Indian Ocean through the coastal Bagamoyo district. Wami river being a major one with total area sizes of 40000 km^2 against Ruvu river that consists of 17700 km^2 (Sumerlin & Gritzner, 2007). The basin extends from the semi-arid central Dodoma region to the humid inland swamps in the Morogoro region to Saadani Village in the coastal Bagamoyo district, also consists of coastal rivers south of Dar es Salaam and spans to an altitudinal gradient of approximately 2260 meters (TANAPA, 2003).

The Wami river receives runoff from residential areas, sugarcane and rice plantations, among other sources located in the catchment areas. Uniquely, the Wami sub-basin comprises one of the world's most important hotspots of biological diversity: the Eastern Arc Mountains and coastal forests (Ngana et al., 2010). The anthropogenic activities commonly in the Wami-Ruvu basin including mining, agriculture, road construction, residential and commercial development (Sawe et al., 2021a).

Sampling plans

For sampling purposes, the river was conceptually divided into three (3) sections as upstream, mid-section and downstream. Mandera (Upper stream), Mkoko (middle stream), and Matipwili (lower stream) villages located along Wami River were found to be areas with active socio-economic activities that involve the use of river water and hence they were considered in sampling points as shown on Figure 1. The selection of sampling points was based on easy accessibility by road for collection of water and sediment samples. However, the basin and river estuary are not in protected areas and human use of natural resources is not restricted and hence seem to be direct effect the natural biodiversity.

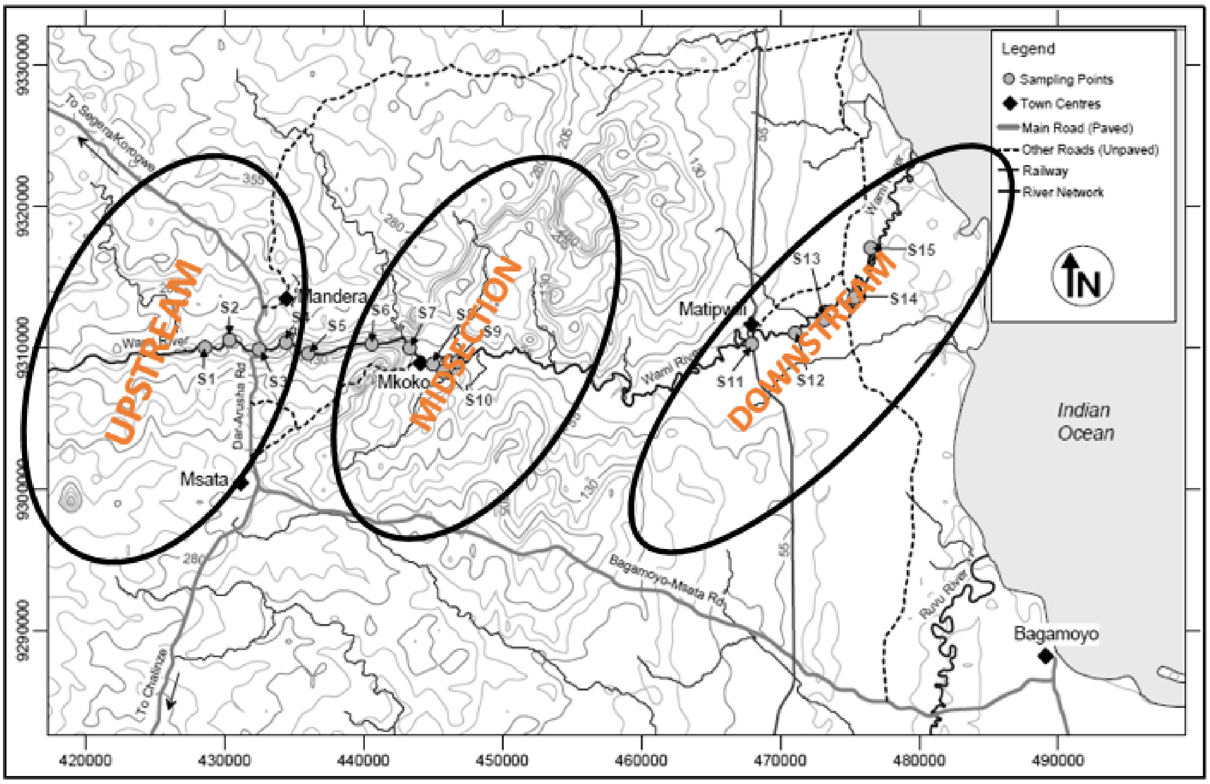

Figure 1: A map showing divided sections and points of a river Wami for sampling purposes

Sample collection preparation and analysis

Water samples

Water sampling was conducted in two seasons, dry and rainy between August 2015 and June 2016 for comparison. Total of 15 water samples were collected by grab sampling technique during each season, 5 samples were taken from random points of each section (upstream, mid and downstream). To study spatial variations of heavy metal pollution, samples were collected at different distances away from the river, from well-mixed section of the river (main stream) 30 cm below the water surface using a weighted bottle. Samples were stored in sterilized polyethylene 300 ml bottles at 4°C and transported to the laboratory at Ardhi University, Dar es Salaam for analysis. Samples for heavy metal parameters (Pb, Zn, Cr, Cd, Ni, Co and Hg) were sampled using Standard Methods for the Examination of Water and Wastewater (APHA, 1998).

In order to determination the heavy metals concentrations all collected samples were prepared. The preparations involved digestion of water samples with aquaregia ($HNO3$ 67%:HCl 37% = 3:1). Atomic Absorption Spectrometry (AAS) was used as common and reliable technique for detecting metals and metalloids in environmental samples.

Sediment samples

The sediment samples were collected by scooping up 10 cm using the local made Bottom-Grab Sampler (corer) of the bed sediment from 10 m away from the river bank and at the middle points, where the water samples were taken. Total of sixty (60) sediment samples were taken and stored in clean labelled plastic bags for easy and safe transportation into the laboratory for characterization and elemental analysis. In the laboratory, sediment samples were air-dried at room temperature (25°C ± 2) for seven days, then all debris materails were removed. The air dried sediment samples were grinded using a morter and pastle to get powder form and seiving was done to obtain a hmogeneous mass. The 2 g of each powder sediment sample was digested following the standard procedure by placing 2g of in a 50 ml crucible before the addition of 10 ml concentrated HNO_3. The mixture was placed on a hot plate for 30–45 min to allow for oxidation. After cooling, 2.5 ml of concentrated (70%) HClO4 acid was added and the mixture was reheated on a hot plate until the digest became clear and semi dried. After that the samples were cooled and filtered through Whatman number 42 filter paper and the solution was used for analysis using atomic absorption spectrometry.

Quality assurance

An extensive quality assurance and quality control procedure was followed. Procedures for quality control samples that were analyzed included using the reagent blanks, blanks, sample replicates, holding time consideration, sediment manipulation and storage methods. Standards were applied as per Standard Methods for the examination of water and wastewater (APHA, 1998) which obtained from Ardhi University laboratory, Tanzania were used to monitor the determination quality to ensure data reliability. The detection limit of AAS used in analysis was 0.01 mg/l.

Assessment of heavy metals in sediment

After the analysis of heavy metals in sediment, the degree of contamination were analysed. This was evaluated by three Indices for environmental assessment of Wami river sediment. The indices included two individual indices, Contamination Factor (CF) and Geoaccumulation index (Igeo) while Pollution Load Index (PLI) was an integrated index. In the process of interpreting geochemical data, background values and its choice plays a significant contribution. The most common way is the use ofaverage shale values as suggested by Turekian & Wedepohl, (1961) and average crustal abundance data as reference baselines (Ali, et al., 2016).

Contamination factor (CF) and Pollution load index (PLI)

The CF and PLI together were calculated in order to evaluate the sediment quality. Pollution load index of the allanalysed metals were calculated usingcombined approaches as suggested by Tomlinson, et al.,(1980) and shown in equation 1.

$$PLI= (CF_1\times\ CF_1\times\ CF_1\times\ldots\ldots\times\ CF_n)^{1/n} \qquad \text{(eq.1)}$$

where (contamination factor) $CF_1$is the ratio between the content of metal (1)to the background values (background value from the average shalevalue) for specific metal in sediment (equation 2);

$$CF_{metal}=C_{metal}/C_{background} \qquad \text{(eq.2)}$$

Contamination factor (CF) can be used for monitoring the pollution of one single metal over a period of time, its values have being classified into four grades for evaluation (Jiang et al., 2013).The overall toxicity status and consequence of samples to the contribution of the studied metals can be determined using the obtained PLI value and interpreted using the range

(Table 1) as suggested by Tomlinson, et al., (1980).

Index of Geo-Accumulation (IGEO)

This is another way used to assess the pollution of single metal in sediments and it has been classified in scales of pollution degree (table 1) as proposed by Muller, (1969). In order to characterize the level of pollution in the sediment, $I_{geo}$was calculated using equation 3.

$I_{geo} = \log_2 (C_n / 1.5\ B_n)$

(eq. 3)

Where $C_n$is the is the measured concentration of examined element (n) in the sediment sample and (Bn) is the geochemical background for the element (n) and in this case they are taken from the literature (average shale value) described by Turekian & Wedepohl, (1961). The factor 1.5 is introduced to include possible variation of the background values that are due to lithogenic variations as well as very small anthropogenic influences (Goher, et al., 2014).

Table 1: Pollution classes according to single and integrated indices

CF[1] classes		PLI[2] classes			Igeo[3]classes
CF Value	Pollution	PLI value	Pollution	*I_{geo} value*	Pollution
CF < 1	Low	PLI=0	Excellence	<0-0	Unpolluted
1 ≤ CF < 3	Moderate	PLI=1	Baseline level of pollutants	0-1	Unpolluted to moderated
3 ≤ CF < 6	Considerable	PLI>1	Polluted	1-2	Moderated polluted
CF ≥ 6	Very high			2-3	Moderated-high polluted
				3-4	Highly polluted
				4-5	Highly to extremely polluted
				5-6	Extremely polluted

[1] According to: Gong et al. (2008)

[2] According to: Tomlinson et al. (1980)

[3]According to: Muller (1981)

Statistical Analysis

Descriptive and multivariate statistical analysis were applied to all the heavy metal data obtained from water samples in two seasons which include the mean, standard deviation (SD), the range, and standard error. Moreover, the spatial and temporal or seasonal variations of the observed water quality parameters were evaluated using the coefficient of variation (CV), one-way analysis of variance (ANOVA) at 5 % level of significance and the paired-samples t-test, using IBM SPSS Statistics (*v. 20*) software package. Total concentrations of heavy metals in sediments were analyzed to investigate their distributions and pollution levels in this ecosystem. Moreover, the contamination factor (CF), Index of geoaccumulation (Igeo) and pollution load index (PLI) were adopted to assess the heavy metal contamination levels of river sediment.

RESULTS AND DISCUSSION

Heavy metals in water

Table 2 shows results of heavy metal concentrations in surface waters analysed in mg/l for two seasons together with WHO recommended values per heavy metal (WHO, 2011; WHO, 1993). The average concentration of studied metals in water followed the decreasing order of: Co >Pb >Zn > Ni. Due to the minimum detection limit (0.01mg/l) of atomic adsorption instrument used for heavy metal analysis, *Cr, Cd* and *Hg* were detected below this level (BDL) in both seasons. The obtained results depict that their presence might be very little to be analysed or presented, hence excluded.

Table 2: Heavy metal concentration in water sample (mg/l)

Sampling points	**Pb**		**Zn**		**Ni**		**Co**	
	Dry	**Rainy**	**Dry**	**Rainy**	**Dry**	**Rainy**	**Dry**	**Rainy**
1	0.46	0.05	0.41	0.37	0.04	0.02	0.35	0.19
2	0.02	0.01	0.03	0.01	0.03	0.02	0.19	0.16
3	0.90	0.87	0.04	0.02	0.01	0.11	0.28	0.43
4	0.11	0.07	0.03	0.01	0.01	0.01	0.01	0.01
5	0.09	0.04	0.05	0.03	0.01	0.01	0.01	0.01
6	0.50	0.13	0.37	0.35	0.01	0.01	0.01	0.01
7	0.02	0.01	0.03	0.01	0.09	0.03	0.12	0.11
8	0.08	0.08	0.00	0.05	0.05	0.00	0.01	0.01
9	0.45	0.43	0.02	0.00	0.04	0.05	0.76	0.41
10	0.12	0.08	0.04	0.02	0.01	0.01	0.01	0.01
11	0.02	0.02	0.04	0.02	0.07	0.11	0.01	0.01
12	0.10	0.02	0.08	0.06	0.10	0.05	0.78	0.44
13	0.02	0.34	0.36	0.25	0.09	0.10	0.01	0.01
14	0.37	0.33	0.05	0.03	0.01	0.01	0.56	0.14
15	0.02	0.00	0.02	0.02	0.01	0.03	0.78	0.49
Average ±SD	0.22 ± 0.26	0.17 ± 0.24	0.10 ± 0.14	0.08 ± 0.13	0.04 ± 0.03	0.04± 0.04	0.26 ± 0.31	0.16 ± 0.19
WHO[1]	0.05		0.5		0.02		NA	

[1] According to WHO, 1993; WHO, 2011, NA=Not available

Lead (Pb)

The value of Pb was recorded to range from zero to maximum value of 0.9 mg/L at upstream point of the river. The mean concentration of Pb in water for dry season and rainy season observed to be 0.22 ± 0.26 mg/L and 0.17± 0.24 mg/L respectively, which was much higher than the WHO standard level (0.05 mg/L) for drinking water (WHO, 2011). From the paired-samples *t-test*, the two means of Pb are statistically differences in Pb, t (15) = 0.231, $p < 0.05$ (2-tailed) among the dry and rainy seasons. This parameter however recorded the low range of variance (Var = 0.057-0.068), which indicates closely spread data around the mean value. Lead is the most significant of all the heavy metals because it is toxic, very common and harmful even in small amounts (Tchounwou et al., 2012).The high value of Pb in water has been detected in different places as reported by many researches. Same conditions of high Pb to be detected especially during wet season near the river mouth located along highways has been reported by Henry & Mamboya, (2012) at Simiyu River mouth, in Tanzania specifically at Bariadi bridge. This could be attributed by lead from traffic washed away by runoff down to the water sources. Furthermore, Ali, et al., (2016) reported the values range 0.016 mg/L to 0.09 mg/L analysed using the similar methods from Karnaphuli River water in Bangladesh. Higher values also have been reported in other different geographical areas as percentage of samples that conform the WHO recommended value and found that only 70% of samples taken were within the recommended range(Bouraie et al., 2010; Ferronato et al., 2013).

Zinc (Zn).

Zinc is one of the heavy metal of the concern that play a vital role in the physiological and metabolic process of many organisms, yet in higher concentrations zinc can be toxic to the organism (Rajkovic, et al., 2008). The average concentration of *Zn* was observed 0.10 ± 0.14 mg/L and 0.08 ± 0.13 mg/L during dry and rainy season respectively, minimum, and maximum values were found to be 0.37 and 0.41 mg/L. The recommended standards by WHO, and USEPA show that all found values of Zn in this study obey the recommended standards of 2.0 mg/L (USEPA, 2001; WHO, 2011; Xiao et al., 2012).The paired-samples *t-test*, depicts those two means of Zn are statistically differences, t (15) = 0.02, $p < 0.05$ (2-tailed) among the two compared seasons with range of variance (Var= 0.016-0.021) showing closely spread of data around the mean values. The importance of monitoring Zn in surface water is due to its restricted mobility from the rocks weathering and normally shows fairly low concentrations as depicted by (Tchounwou et al., 2012).In other studies, presence of heavy metals concentration was compared in different media such as water, soil and living organisms in water. In Nigeria for example, a study done in Odo-Ayo River reports that Zn concentration was detected lower than that in fish organs and found to be 4.65mg/L (Edward, et al., 2013)which is higher when compared to that obtained in this study and that recommended by USEPA standards.

Nickel (Ni)

Interestingly, *Ni* did not show much differences in values of different seasons, (0.04 ± 0.03 mg/L) with minimum of 0 to maximum of 0.1 mg/L. Of all samples analysed (n=30), about 33% found to be beyond the permissible recommended value of 0.02 mg/L (WHO, 2011). However, other studies show large amount of Ni that found to be within different international standards with amounts range 0.002 mg/L to 0.06 mg/L from different surface water sources (Öztürk, et al., 2009).

Cobalt (Co)

The average level of Cobalt was 0.26 ± 0.31 mg/L and 0.16 ± 0.19 mg/L for dry and rainy seasons respectively. Cobalt concentration was found to be below the detection limit in six of the sampling areas in dry season and seven of sampling areas in rainy season. In the other areas, cobalt concentration ranges from 0.01mg/L and maximum of 0.78 mg/L was detected from downstream point during dry season. The WHO guidelines does not show a permissible limits of *Cobalt* in surface water, but comparing with USEPA guidelines, 50% of samples (n=30) were found to be beyond the recommended 0.1 mg/L (USEPA, 2001). The paired-samples t-test, exhibits those two means of Co among the two compared seasons are statistically differences, t (15) = 0.046, $p < 0.05$ (2-tailed) with a range of variance

(Var = 0.035-0.097) which indicates a spread data around the mean value.

Heavy Metal Distribution in River Sediment

Table 3 shows a summary of heavy metals results from river sediments analysed in two seasons. The overall average concentration of studied metals in sediments followed the decreasing order of: Cr>Zn > Co>Pb >Ni > Cd. Mean contents of Cr in the river sediment were recorded with highest concentration of other metals. It ranges from 0.01 mg/kg at the mid-section of the rivers (Point 10 and 11) in both seasons to 2.54 mg/kg at the first point of downstream. Following Zn, exhibits almost similar values in dry and rainy season with average mean of 0.44 ± 0.38 mg/kg and 0.41± 0.36 mg/kg respectively and maximum value of 0.98 mg/kg be detected at point 11, downstream section. Cobalt shows no changes in season with average of 0.38 mg/kg. however, the highest value (0.89 mg/kg) was detected almost to the end points of the downstream section at point 13. Interestingly, Pb with regardless of amount, it was detected in almost all samples except from last downstream point (15) with a range of 0.01 to 0.73 mg/kg. Ni and Cd depict lower concentrations that range from 0.01 mg/kg to 0.91 mg/kg and from 0.01 mg/kg to 0.44 mg/kg respectively, with random patterns in points. Mercury (Hg) was detected below the detection (BDL) limit of atomic adsorption instrument used for heavy metal analysis in both seasons. Spatially, it is noted that the mean concentration of metals in downstream and upstream has increased from dry periods to rainy period. However, there is no uniform seasonal variations of heavy metal concentration between rainy and dry season.

Table 3. Levels of studied heavy metals of Wami river sediment during dry season and rainy season (mg/kg)

Sampling points	Pb		Zn		Cr		Cd		Ni		Co		Hg	
	D	**R**	**D**	**R**	**D**	**R**	**D**	**R**	**D**	**R**	**D**	**R**	**D**	**R**
1	0.28	0.38	0.76	0.79	0.86	1.04	0.01	0.21	0.75	0.82	0.67	0.60	BDL	BDL
2	0.13	0.12	0.47	0.67	0.84	0.86	0.25	0.35	0.36	0.32	0.59	0.59	BDL	BDL
3	0.61	0.73	0.78	0.70	0.86	1.06	0.02	0.00	0.12	0.20	0.01	0.01	BDL	BDL
4	0.06	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	BDL	BDL
5	0.05	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	BDL	BDL
6	0.14	0.07	0.70	0.30	0.64	0.58	0.35	0.33	0.25	0.20	0.01	0.01	BDL	BDL
7	0.17	0.08	0.53	0.58	0.49	0.37	0.34	0.39	0.17	0.06	0.63	0.74	BDL	BDL
8	0.03	0.06	0.85	0.82	0.50	0.65	0.32	0.40	0.28	0.16	0.19	0.15	BDL	BDL
9	0.39	0.19	0.01	0.01	0.01	0.01	0.01	0.01	0.08	0.04	0.60	0.64	BDL	BDL
10	0.04	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	BDL	BDL
11	0.28	0.24	0.98	0.84	0.60	0.63	0.44	0.43	0.01	0.01	0.16	0.07	BDL	BDL
12	0.88	0.70	0.79	0.75	2.40	2.54	0.36	0.41	0.91	0.89	0.81	0.85	BDL	BDL
13	0.24	0.26	0.67	0.60	0.35	0.13	0.13	0.16	0.11	0.13	0.89	0.79	BDL	BDL
14	0.18	0.18	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.51	0.55	BDL	BDL
15	0.01	0.01	0.02	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.66	0.64	BDL	BDL
Average ± SD	**0.23 ± 0.24**	**0.21 ± 0.23**	**0.44 ± 0.38**	**0.41 ± 0.36**	**0.51 ± 0.63**	**0.53 ± 0.68**	**0.15 ± 0.17**	**0.18 ± 0.18**	**0.21 ± 0.28**	**0.19 ± 0.29**	**0.38 ± 0.33**	**0.38 ± 0.34**		

BDL=Below detection limit; D= Dry season; R=Rainy season; SD=Standard Deviation

Heavy metals pollution levels

Single pollution index analysis of heavy metals

Contamination Factor (CF)

Contamination Factor (CF=metal content in the sediment/background level of metal) is used to identify degree of contamination. Background level of metal was obtained with respect to the widely used average shale values (ASV). According to Turekian & Wedepohl, (1961), the ASV of the analysed metals are: Pb, 20 mg/kg; Zn, 95 mg/kg;Cr, 90 mg/kg; Cd, 0.3 mg/kg; Ni, 68 mg/kg and Co, 19 mg/kg.

Table 4: Contamination Factors (CF) of studied Heavy metals in river sediment for different seasons

	Dry season						Rainy season					
Sampling points	**Pb**	**Zn**	**Cr**	**Cd**	**Ni**	**Co**	**Pb**	**Zn**	**Cr**	**Cd**	**Ni**	**Co**
1	0.01	0.01	0.01	0.03	0.01	0.04	0.02	0.01	0.01	0.69	0.01	0.03
2	0.01	0.00	0.01	0.83	0.01	0.03	0.01	0.01	0.01	**1.17**	0.00	0.03
3	0.03	0.01	0.01	0.06	0.00	0.00	0.04	0.01	0.01	0.01	0.00	0.00
4	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
5	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
6	0.01	0.01	0.01	**1.18**	0.00	0.00	0.00	0.00	0.01	**1.11**	0.00	0.00
7	0.01	0.01	0.01	**1.13**	0.00	0.03	0.00	0.01	0.00	**1.29**	0.00	0.04
8	0.00	0.01	0.01	**1.07**	0.00	0.01	0.00	0.01	0.01	**1.35**	0.00	0.01
9	0.02	0.00	0.00	0.03	0.00	0.03	0.01	0.00	0.00	0.03	0.00	0.03
10	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
11	0.01	0.01	0.01	**1.47**	0.00	0.01	0.01	0.01	0.01	**1.43**	0.00	0.00
12	0.04	0.01	0.03	**1.20**	0.01	0.04	0.03	0.01	0.03	**1.37**	0.01	0.04
13	0.01	0.01	0.00	0.43	0.00	0.05	0.01	0.01	0.00	0.52	0.00	0.04
14	0.01	0.00	0.00	0.03	0.00	0.03	0.01	0.00	0.00	0.03	0.00	0.03
15	0.00	0.00	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.03

The CF values of all studied metals presented in table 4 obtained as shown in section 2.1.4 using equation 2 used to study the level of contamination of river sediment. Cadmium in some of sampling points shows moderate pollution degree with CF value ≥ 1 (table 1) in both seasons. Five (5) during dry season (points 6, 7, 8, 11 and 12) and six (6) points during rainy season (points 2, 6, 7, 8, 11, 12). The rest of studied metals were found to be less than 1 in all sites indicating no pollution and the Wami river sediment is in good quality.

Index of Geo-accumulation (IGEO)

The geo-accumulation index *Igeo* values were calculated for the studied metals using equation 3, as introduced Muller, (1969).

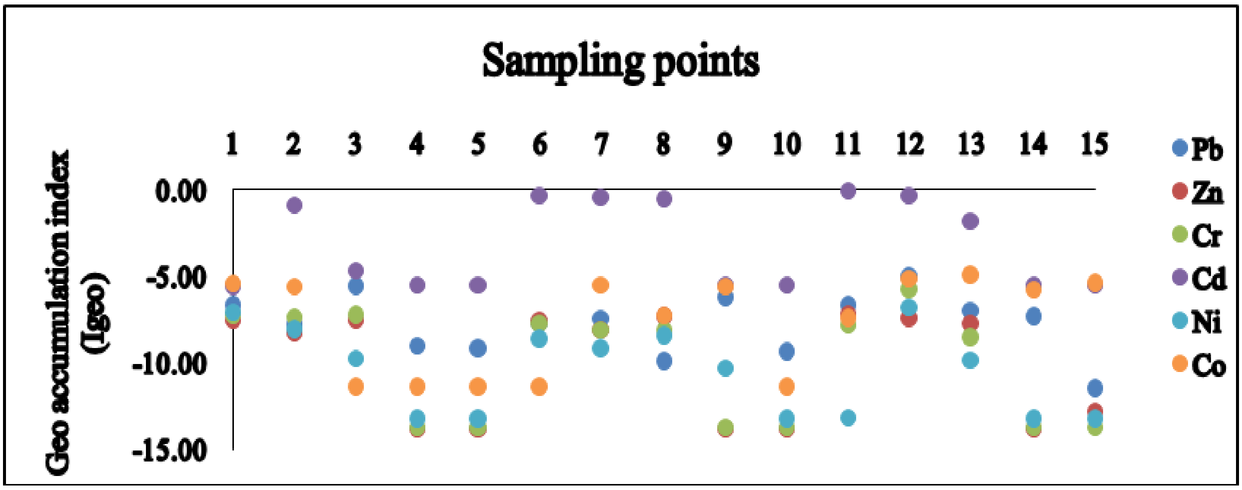

Figure 2a: Index of geo- accumulation (Igeo) values of measured trace metals in Wami river sediments on dry season

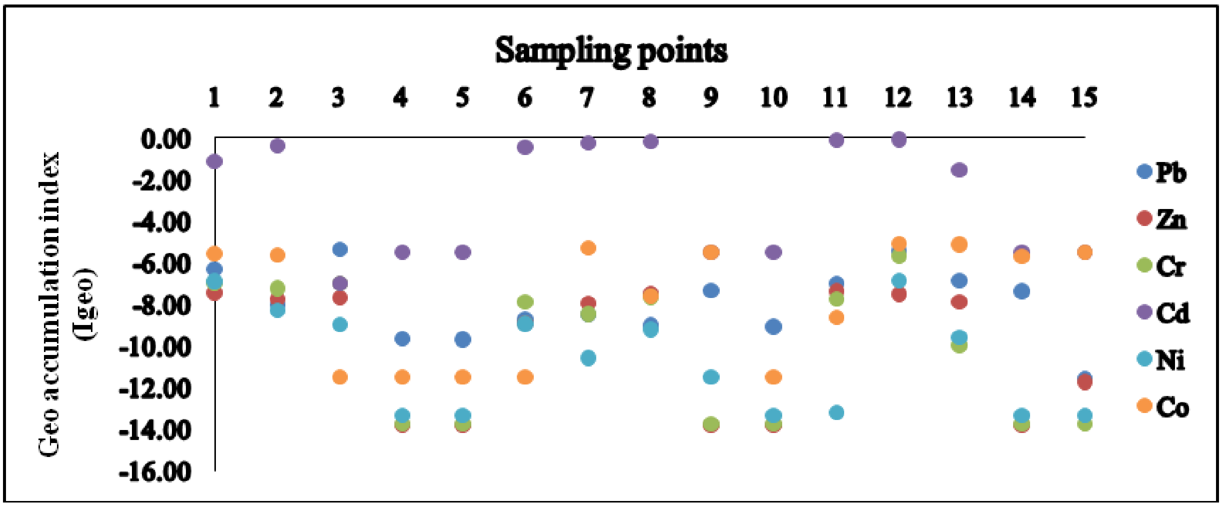

Figure 2b. Figure 2a. Index of geo- accumulation (Igeo) values of measured trace metals in Wami river sediments on rainy season

The calculated index of geo-accumulation (*Igeo*) of the investigated trace metals in the sediments of Wami river are illustrated in Figures 2a and 2b. The *Igeo* values obtained range from -13.80 to 0.03 during the dry season and -13.80 t0 0.00 in rainy season. For all studied trace metals exhibited a zero class that correspond to contamination intensity that indicating unpolluted sediment quality since all the values are less than zero.

Pollution load index (PLI)

The pollution load index (PLI) was used to measure PLI in sediments of Wami river and results are presented in Table 5. PLI provides simple comparative means for assessing a site or area quality. The interpretations of PLI values as proposed by Tomlinson et al., (1980) is considered as shown in table 1.

Table 5: Pollution load index (PLI) of six (6) calculated heavy metals in different Wami river sections

River sections	Sampling points	PLI (dry season)	Average per section (dry season)	PLI (rainy season)	Average per section (rainy season)
Upper	**1**	0.015		0.028	
	2	0.019		0.020	
	3	0.007		0.006	
	4	0.001		0.001	
	5	0.001	0.008	0.001	0.011
Mid	**6**	0.010		0.007	
	7	0.017		0.013	
	8	0.012		0.013	
	9	0.003		0.002	
	10	0.001	0.008	0.001	0.007
Down	**11**	0.011		0.009	
	12	0.043		0.043	
	13	0.015		0.013	
	14	0.002		0.002	
	15	0.001	0.014	0.001	0.014

PLI values of sediments in the different river sections ranged from 0.001 to 0.043 in both seasons, with average of 0.007 to 0.014 among the river sections. Based on pollution categories (table 1), all PLI calculated in different sampling sites and as average for river sections found to be less than 1, which means the water show an 'excellent' quality in terms of pollution degree.

CONCLUSION

The study analyzed selected heavymetals from water and sediment of wami River. This was accelerated by an increase in anthropogenic activities at upstream level resulting into effect to the downstream. Overall results showed that the heavy metal element concentrations in Wami River water and sediments were mainly within the permissible limits according to WHO (2011) and USEPA (2001). However, significant local water pollution problems were found. Due to the increasing runoff taken along from different sources and drain into the river and an extensive water use, the deterioration of the quality of river water has been noticed.

The distribution of heavy metals under investigation in water samples show a decrease pattern of Co > Pb > Zn > Ni while three other metals (Cr, Cd and Hg) were detected below the detection limit of an instrument used. Among seven heavy metals analysed from water samples, Pb shows high concentrations in both seasons beyond the recommended value by WHO standards. Again 50% of analysed samples found to have Co concentration beyond the recommended USEPA (2001) standards. Generally, water samples show a slight temporal increase in heavy metals concentration from dry season to rainy season and a spatial decrease of heavy metal concentration from upstream to downstream of the river.

Heavy metals concentration as well as pollution degree of Wami River sediment were classified by using two individual metal indices (contamination factor (CF) and Index for geo accumulation (Igeo) and one combined index (Pollution load index (PLI). Despite of small amount of heavy metals found in water and sediment of the River, all three indices used concluded that Wami river sediment is in good quality and graded as unpolluted as a pollution degree. It has been noticed that to provide a more accurate and comprehensive assessment of the risk of heavy metals to the environment, a complementary approach should be considered including assessment of different methods using Indices and multivariate statistical analyses. However, a systematic investigation to monitor metal loading and other potential changes in the river sediment quality is recommended.

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REFERENCES

Ali, M. M., Ali, M. L., Islam, M. S., & Rahman, M. Z. (2016). Preliminary assessment of heavy metals in water and sediment of Karnaphuli River, Bangladesh. *Environmental Nanotechnology, Monitoring and Management*, *5*, 27–35. https://doi.org/10.1016/j.enmm.2016.01.002

Anyanwu, B. O., Ezejiofor, A. N., Igweze, Z. N., & Orisakwe, O. E. (2018). Heavy metal mixture exposure and effects in developing nations: An update. *Toxics*, *6*(4), 1–32. https://doi.org/10.3390/toxics6040065

Bouraie, M. M. El, Barbary, A. A. El, Yehia, M. M., & Motawea, E. A. (2010). *Heavy metal concentrations in surface river water and bed sediments at Nile Delta in Egypt*. *61*(1).

Briffa, J., Sinagra, E., & Blundell, R. (2020). Heavy metal pollution in the environment and their toxicological effects on humans. *Heliyon*, *6*(9), e04691. https://doi.org/10.1016/j.heliyon.2020.e04691

Edward, J. B., Idowu, E. O., Oso, J. A., & Ibidapo, O. R. (2013). *Determination of heavy metal concentration in fish samples , sediment and water from Odo-Ayo River in*. *1*(1), 27–33. https://doi.org/10.11648/j.ijema.20130101.14

FAO. (2017). *FAO/INFOODS global food composition database for pulses Version 1.0 - uPulses1.0* (F. Grande, B. Stadlmayr, M. Fialon, S. Dahdouh, D. Rittenschober, T. Longvah, & U. R. Charrondiere (eds.)). Food and Agriculture Organization. http://www.fao.org/infoods/infoods/tables-and-databases/faoinfoods-databases/en/

Ferronato, C., Antisari, L. V., Modesto, M., & Vianello, G. (2013). Speciation of Heavy Metals At Water-Sediment Interface Speciation Des Metaux Lourds Aux Interfaces Eau-Sediment

Speciazione Di Metalli Pesanti All'Interfaccia Acqua-Sedimento. *EQA – Environmental Quality*, *10*, 51–64. https://doi.org/10.6092/issn.2281-4485/3932

Goher, M. E., Hassan, A. M., Abdel-moniem, I. A., Fahmy, A. H., & El-sayed, S. M. (2014). Evaluation of surface water quality and heavy metal indices of Ismailia Canal , Nile River , Egypt. *The Egyptian Journal of Aquatic Research*, *40*(3), 225–233. https://doi.org/10.1016/j.ejar.2014.09.001

Guo, W., Liu, X., Liu, Z., & Li, G. (2010). *Pollution and Potential Ecological Risk Evaluation of Heavy Metals in the Sediments around Dongjiang Harbor , Tianjin*. *2*(5), 729–736. https://doi.org/10.1016/j.proenv.2010.10.084

Henry, L., & Mamboya, F. A. (2012). Distribution of Metals along Simiyu Wetland of Lake Victoria Basin and its Impact on Agriculture. *Journal of Wetlands Ecology*, *2012*(6), 31–43.

Hu, B., Zhou, J., Liu, L., Meng, W., & Wang, Z. (2017). Assessment of Heavy Metal Pollution and Potential Ecological Risk in Soils of Tianjin Sewage Irrigation Region, North China. *Journal of Environmental & Analytical Toxicology*, *07*(01), 1–6. https://doi.org/10.4172/2161-0525.1000425

Jiang, M., Zeng, G., Zhang, C., Ma, X., Chen, M., Zhang, J., Lu, L., Yu, Q., Hu, L., & Liu, L. (2013). Assessment of Heavy Metal Contamination in the Surrounding Soils and Surface Sediments in Xiawangang River, Qingshuitang District. *PLoS ONE*, *8*(8). https://doi.org/10.1371/journal.pone.0071176

Kiwango, H., Njau, K. N., & Wolanski, E. (2015). The need to enforce minimum environmental flow requirements in Tanzania to preserve estuaries: Case study of mangrove-fringed Wami River estuary. *Ecohydrology and Hydrobiology*, *15*(4), 171–181. https://doi.org/10.1016/j.ecohyd.2015.09.002

Mero, R. (2011). *Assessment of water quality and spatial distribution of the major pollutants in Ngerengere river catchment, Tanzania* (Issue June).

Muller, G. (1969). Index of geoaccumulation in sediments of the Rhine River. *Geol. J.*, *2*, 109–118.

Ngana, J., Mahay, F., & Cross, K. (2010). *Wami Basin: A Situation Analysis*.

Nobert, J., & Skinner, J. (2016). Meeting future demand for drinking water supply in Dar es Salaam: Hydrological modelling of the Ruvu River and assessment of flows. In *International Institute for Environment and Development*.

Öztürk, M., Özözen, G., Minareci, O., & Minareci, E. (2009). *Determinantion of heavy metals in fish,water and sediments of Avsar dam lake in Turkey*. *6*(2), 73–80.

Paul, D. (2017). Annals of Agrarian Science Research on heavy metal pollution of river Ganga : A review. *Annals of Agrarian Sciences*, *15*(2), 278–286. https://doi.org/10.1016/j.aasci.2017.04.001

Rajkovic, M.B., Lacnjevac, C. M., Ralevic, N. R., Stojanovic, M. D., Toskovic, D. V., Pantelic, G. K., Ristic, N. ., & Jovanic, S. (2008). Identification of metals (heavy and radioactive) in drinking water by indirect analysis method based on scale tests. *Sensors*, *8*, 2188–2207.

Sawe, S. F., Shilla, D. A., & Machiwa, J. F. (2021a). Assessment of Ecological Risk of Heavy Metals Using Probabilistic Risk Assessment Model (AQUARISK) in Surface Sediments from Wami Estuary, Tanzania. *BioMed Research International*, *2021*. https://doi.org/10.1155/2021/6635903

Sawe, S. F., Shilla, D. A., & Machiwa, J. F. (2021b). Reconstruction of metal(loid)s pollution history in sediments of Wami Estuary, Indian Ocean Coast of Tanzania. *Environmental Forensics*, *0*(0), 1–14. https://doi.org/10.1080/15275922.2021.1913676

Sumerlin, D., & Gritzner, J. (2007). *Interdependence of the Wami River to the Ecosystems and Biodiversity of Saadani National Park, United Republic of Tanzania,”.*

TANAPA. (2003). *Saadani National Park, Management Zone Plan Environmental Impact Assessment*.

Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K., & Sutton, D. J. (2012). Molecular, clinical and environmental toxicicology Volume 3: Environmental Toxicology. *Molecular, Clinical and Environmental Toxicology*, *101*, 133–164. https://doi.org/10.1007/978-3-7643-8340-4

Tomlinson, D. ., Wilson, J. G., Harris, C. R., & Jeffrey, D. . (1980). *Problems in assessment of heavy-metal levels in estuaries and the formation of a pollution index*. *575*, 566–575.

Turekian, K. K., & Wedepohl, K. H. (1961). Distribution of the elements in some major units of the earth’s crust. *Geol. Soc. Am. Bull*, *72*, 175–192.

URT. (2014). Water Sector Development Programme Phase II. In *Ministry of WAter* (Issue July 2014).

USEPA. (2001). *National Primary Drinking Water Standards*. http://www.epa.gov/safewater/contaminants/index.html. 43

Weiss, T. F., Leuzinger, M., Zurbrugg, C., & Eggen, R. I. . (2016). *Chemical Pollution in Low- and Middle-Income Countries*. Swiss Federal Institute of Aquatic Science and Technology Überlandstrasse 133, 8600.

WHO. (2006). WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater, Volume IV- Excreta and Greywater Use in Agriculture. *World Health*, *II*, 204. https://doi.org/10.1007/s13398-014-0173-7.2

WHO. (2011). Guidelines for drinking-water quality. In *WHO Library Cataloguing-in-Publication* (Vol. 38, Issue 4). https://doi.org/10.1016/S1462-0758(00)00006-6

Xiao, R., Bai, J., Gao, H., Huang, L., Huang, C., & Liu, P. (2012). Heavy metals (Cr and Ni) distribution and fractionation in cropland soils from reclaimed tidal wetlands in Pearl River estuary, South China. *Procedia Environmental Sciences*, *13*(2011), 1684–1687. https://doi.org/10.1016/j.proenv.2012.01.161

Yanda, P. ., & Munishi, P. K. . (2007). *Hydrologic and land use/cover change analysis for the Ruvu river (Uluguru) and Sigi river (East Usambara) Watersheds* (Issue April).