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Determination of Pollutant Levels in Water of River Challawa and in Tap Water from Kano Industrial Area, Kano State, Nigeria

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Abstract: Concentration of dissolved copper (Cu), cobalt (Co), zinc (Zn), iron (Fe), lead (Pb), manganese (Mn), chromium (Cr), as well as pH, redox potential (Eh), dissolved oxygen (DO), Total Dissolved Solid (TDS), temperature, nitrate, sulphate and phosphate were determined in River Challawa and tap water from Challawa, Sharada and Bompai industrial areas, Kano State, Nigeria. Samples were collected for a period fifteen weeks. River Challawa is the main water supply source for Kano town and numerous industries within this area. Apart from being a source of water supply, it serves as a sink for industrial and municipal wastes. These parameters were simultaneously monitored. Physico-chemical examination revealed that the levels of pH (6.81±0.10 to 10.23±0.32), Eh (-46.3±1.34 to -87.2±1.54 mV), TDS (40.3±3.24 to 70.1±8.40 mg L⁻¹), temperature (8.2±0.14 to 12.8±0.24°C), sulphate (22.6±0.21 to 43.5±0.31 mg L⁻¹) and nitrate (1.11±0.02 to 4.04±0.03 mg L⁻¹) in River Challawa and tap water from Challawa, Sharada and Bompai industrial areas were below the maximum permissible limits set by WHO and Federal Environmental Protection Agency (FEPA) Nigeria for drinking water and aquatic ecosystem. Concentration of heavy metals; Cu, Co, Zn, Fe, Pb, Mn and Cr in River Challawa were significantly above the maximum allowable levels set by United State Environmental Protection Agency (USEPA) and WHO levels for drinking water and for protection of aquatic ecosystem, while for tap water the concentration of heavy metals were within safe limits. The levels of DO and phosphate in River Challawa exceeded the FEPA tolerance limits for drinking water and water meant for domestic uses. This may have deleterious effect on aquatic ecosystem and the health of the rural dwellers that use the river water directly for domestic purposes without treatment.

Key words: Pollutant concentrations, river Challawa, tap water, Kano

INTRODUCTION

The problem of pollution is attracting the attention of people around the world. With increased urbanization and industrialization, there has been a rapid increase in the municipal water (Sewage water and Industrial effluents), which in turn has intensified the environmental pollution. The disposal of industrial effluents and municipal wastes is therefore a major problem for big cities. The major sources of contamination in surface water can be traced to industrial discharges, domestic waste disposal and application of agrochemicals on farmlands (Eletta, 2005).

Human mediation activities have locally and episodically introduce numerous potentially hazardous metals to the environment since the onset of industrial revolution (Nriagu, 1996; Celik *et al.*, 2005; Yang and Rose, 2005; Udosen *et al.*, 2006). Aquatic ecosystems are very vulnerable to water pollution. Concern over the environmental, aquatic and human health impacts associated

with heavy metals distributions and concentrations in aquatic environments have a long history (Sastri and Tyagi, 1982). Notably aquatic ecosystems are often polluted with anomalously high levels of toxicants (organic and inorganic substances), which find their way into the aquatic systems with wastewater and effluents generated from industrial enterprises (Yang and Rose, 2005). Heavy metal accumulation in aquatic ecosystem shows that they are accumulated either in aquatic organisms or human upon consumption of these organisms (Matagi *et al.*, 1998; Riba *et al.*, 2003; Essien and Nsikak, 2006).

Heavy metals are non-biodegradable and they persist in the environment and may become concentrated up the food chain (Eja *et al.*, 2003), leading to enhanced levels in liver and muscle tissues of fishes (Eja *et al.*, 2003), aquatic bryophytes (Mouvet *et al.*, 1993) and aquatic biota (Ramos *et al.*, 1999). It therefore means that the biota and water quality of an aquatic ecosystem could determine the quantitative and qualitative levels of heavy metals in tissues of fauna and flora of the ecosystem. Besides physico-chemical parameters, untreated effluents, accidental oil spills; wastewaters from industries could directly or indirectly influence the hydro-biochemical integrity of aquatic ecosystems (Eja *et al.*, 2003).

Industrial discharge is a major component of water pollution, concentration of oxygen demand and nutrient loading of the water bodies, promoting toxic algal blooms and leading to a destabilization of the aquatic ecosystem (Morrison *et al.*, 2001; WRC, 2000; Santchi, 2001). The problem of water pollution is compounded in areas where wastewater treatment systems are simple and not efficient, as is the case of Challawa industrial area where effluents from industries are discharged into River Challawa, with little or no treatment.

Kano (Lat. 11° 59 m 18.3s N, Long 08° 32 m 05.8s E) 418 m above sea level is located in Kano State, occupies central position of Northern Nigeria. Industrially, it is one of the most developed cities in Northern Nigeria and tannery and textile are some of its dominating industries. River Challawa (Lat 11° 52 m 41s N, Long 08° 28 m 09s E) 515 m above sea level originate from the Challawa Gorge dam in Challawa village and stretches down to River Kano where it empties into Lake Chad. The river receives waste from tanneries and textile industries, urban water storm and agricultural runoff from farming communities along the river course. River Challawa serves as washing, fishing, farming and drinking water for communities along these areas. The domestic water supply for Challawa, Sharada and Bompai industrial areas and the surrounding environment in general comes from River Challawa.

This research was therefore carried out in order to assess the physico-chemical parameters of the water body in River Challawa and tap water from Challawa, Sharada and Bompai industrial areas, Kano state, Nigeria. And it is hoped that the results would add to the existing data and could be helpful in defining future waste management practices in the area in terms of quality of waste to be discharged.

MATERIALS AND METHODS

Sampling Points

Measurement points from the sampling sites have been designated Point Source (PS), 1 and 4 m and these points reflect different activities along the watercourse of river Challawa. Point PS was located at the inlet of the discharge of waste effluent into river Challawa. Point 1 m was the point located approximately 100 m after the effluent discharge point into river Challawa. Point 4 m was located 400 m downriver from PS. Tap-water from Challawa, Sharada and Bompai industrial areas were also samples for analysis.

Sample Collection

Water samples were monitored through regular weekly grab sample collections for fifteen weeks. Grab samples were collected five times a week at specified periods, between the periods of September to December, 2005.

Water samples were collected with the aid of clean 1 L capacity plastic bottles, filtered, labeled and treated with 1.5 cm³ of concentrated HNO₃ to give a pH <2 (Radojevic and Bashkin, 1999), previously cleaned by washing in non-ionic detergent, rinsed with tap water and later soaked in 10% HNO₃ for 72 h and finally rinsed with deionised water prior to usage.

During sampling, sample bottles were rinsed with sampled water three times and then filled to the brim at a depth of one meter below the water surface from the three designated sampling points in River Challawa. At each sampling points, three water samples were drawn at random from three points and pooled. While for tap water, the tap was turned on and the water was allowed to run the first streams for some minutes. The bottle was then filled with a gentle flow of water; cover replaced, labeled and kept in the ice bath. The samples were transported to the Laboratory immediately and stored in the refrigerator at about 4°C prior to analysis.

Determination of pH, Eh, Temperature, Dissolved Oxygen and Total Dissolved Solid in Water Sample

Standard methods were followed in determining the following variable pH, redox potential (Eh), Dissolved Oxygen (DO), Total Dissolved Solids (TDS), temperature and heavy metals concentration (USEPA, 1991).

All field meters and equipment were checked and calibrated according to the manufacturers specifications. The pH meter was calibrated using buffers of pH 4.0, 7.0 and 10.0; (HACH, 1997). Total Dissolved Solid (TDS) meter was calibrated using the potassium chloride solution provided by the manufacturer (HACH, 1997). Dissolved Oxygen (DO) meter was calibrated prior to measurement with the appropriate traceable calibration solution of 5% HCl in accordance with the manufacturers instruction.

In situ measurements for some of the parameters pH, Eh and temperature (°C) were measured using WTW pH Electrode SenTix 41. Dissolved oxygen was measured with Jenway Model 9070 waterproof DO meter while TDS was determined by using a C0150 conductivity meter.

Determination of Nitrate, Sulphate and Phosphate in Water Sample

The concentration of sulphate, nitrate and phosphate were determined using a DR/2010 HACH Portable Data Logging Spectrophotometer. The spectrophotometers (HACH DR2010) were checked for malfunctioning by passing standard solutions of all the parameters to be measured; Blank samples (deionized water) were passed between every three measurements of water samples to check for any eventual contamination or abnormal response of equipment.

The concentration of phosphate in the samples were determined using the ascorbic acid method by reacting it with added reagent containing molybdate and an acid to give a blue coloured complex (Standard methods, 1976; DWAF, 1992).

Nitrate as N was determined by the cadmium reduction metal method 8036 (Standard Methods, 1976; DWAF, 1992). The cadmium metal in the added reagent reduced all nitrate in the sample to nitrite; while sulphate was determined by using Sulfa Ver methods 8051 (Standard Methods, 1976; DWAF, 1992).

Determination of Heavy Metals in Water Sample

Heavy metals (copper, cobalt chromium, iron, zinc, manganese and lead) were determined using Atomic Absorption Spectrophotometer (AAS, Unicam 969). The water samples were digested as follows. 100 cm³ of the sample were transferred into a beaker and 5 mL concentrated HNO₃ were added. The beaker with the content was placed on a hot plate and evaporated down to about 20 cm³. The beaker was cooled and another 5 cm³ concentrated HNO₃ was also added. The beaker was covered with watch glass and returned to the hot plate. The heating was continued and then small portion of

HNO₃ was added until the solution appeared light coloured and clear. The beaker wall and watch glass were washed with distilled water and the sample was filtered to remove some insoluble materials that could clog the atomizer. The volume was adjusted to 100 cm³ with distilled water (Radojevic and Bashkin, 1999). Dissolved concentrations of heavy metals in the water samples were determined using Atomic Absorption Spectrophotometer (AAS, Unicam 969) as described in the manufacturers instruction manual.

Data Analysis

Results were subjected to analysis of variance using the general linear models (Proc GLM) procedure of the statistical analysis system program package. Proc Univariate procedure was carried out on residuals to support the assumptions of normality made by the researchers. Where a significant Fisher test was observed, treatment means were separated using the Least Significant Difference at $p < 0.05$.

RESULTS AND DISCUSSION

The mean concentrations of (pH, Eh, DO, TDS, sulphate, nitrate, phosphate and temperature) at PS, 1 and 4 m locations of River Challawa (Table 1) ranged from 8.12 ± 0.10 to 9.23 ± 0.32 for pH; -46.3 ± 1.34 to -87.2 ± 1.54 mV for Eh; 5.67 ± 0.54 to 7.55 ± 0.14 mg L⁻¹ for DO; 40.3 ± 3.24 to 70.1 ± 8.40 mg L⁻¹ for TDS; 8.2 ± 0.14 to 12.8 ± 0.24 °C for temperature; 22.6 ± 0.21 to 45.50 ± 0.31 mg L⁻¹ for sulphate; 1.11 ± 0.02 to 4.04 ± 0.03 mg L⁻¹ for nitrate; 0.54 ± 0.02 to 1.56 ± 0.04 mg L⁻¹ for phosphate, levels of the above parameters were higher at point PS than those from point 1 and 4 m with exception of Eh and DO.

The mean concentrations of (pH, Eh, DO, TDS, sulphate, nitrate, phosphate and temperature) in tap water from Challawa, Sharada and Bompai industrial areas (Table 2) have shown that the concentration ranged from 8.00 ± 0.11 to 8.45 ± 0.12 for pH; -34.30 ± 1.24 to -35.20 ± 1.34 mV for Eh; 3.20 ± 0.24 to 3.24 ± 0.21 mg L⁻¹ for DO; 30.53 ± 1.24 to 31.21 ± 1.20 mg L⁻¹ for TDS; 8.2 ± 0.14 to 9.12 ± 0.12 °C for temperature; 33.23 ± 1.31 to 32.50 ± 1.26 mg L⁻¹ for sulphate; 3.47 ± 0.07 to 3.53 ± 0.01 mg L⁻¹ for nitrate; 0.06 ± 0.01 to 0.06 ± 0.02 mg L⁻¹ for phosphate, respectively.

The mean concentrations of heavy metals from River Challawa at point PS, 1 and 4 m ranged from 0.32 ± 0.02 to 0.57 ± 0.05 mg L⁻¹ for Cu; 0.37 ± 0.01 to 0.66 ± 0.04 mg L⁻¹ for Co; 5.86 ± 0.41 to 7.13 ± 0.56 mg L⁻¹ for Zn; 1.16 ± 0.11 to 2.39 ± 0.14 mg L⁻¹ for Mn; 0.09 ± 0.01 to 2.15 ± 0.04 mg L⁻¹ for Pb; 5.32 ± 0.21 to 10.28 ± 0.31 mg L⁻¹ for Fe and from 0.45 ± 0.01 to 0.97 ± 0.31 mg L⁻¹ for Cr, respectively (Table 3). The concentrations of the heavy metals were higher at point PS than those from point 1 and 4 m. The high values might be attributed to municipal waste and discharge of wastewater from industries sited along this area into point PS. Co and Cu exhibited very low concentrations compared to other metals. Fe and Zn recorded the highest concentration at all the samples points (Table 3). In general, the order of metal content mean concentration is Fe > Zn > Mn > Pb > Cr > Co > Cu, respectively.

The mean concentrations of heavy metals for tap water from Challawa, Sharada and Bompai industrial areas (Table 4) have shown that the concentration ranged from 0.03 ± 0.01 to 0.04 ± 0.01 mg L⁻¹ for Cu; 0.12 ± 0.02 to 0.13 ± 0.03 mg L⁻¹ for Co; 0.23 ± 0.01 to 0.23 ± 0.01 mg L⁻¹ for Zn; 0.04 ± 0.02 to 0.04 ± 0.02 mg L⁻¹ for Mn; 0.04 ± 0.01 to 0.04 ± 0.01 for Pb; 0.13 ± 0.04 to 0.14 ± 0.04 mg L⁻¹ for Fe and 0.02 ± 0.01 to 0.02 ± 0.02 mg L⁻¹ for Cr.

Generally the pH value from River Challawa and tap water were within WHO and Federal Environmental Protection Agency (FEPA) Nigeria standards of 7.5-8.5 for drinking water (DAWF, 1996; Anthony, 1977) from Table 1 and 2. The EU also sets pH protection limits of 6 to 9 for fisheries and aquatic life. The pH obtained from this study fell below this range. Based on these

Table 1: Concentrations of pH, Eh, DO, TDS, temperature, SO_4^{2-} , NO_3^- and PO_4^{3-} in River Challawa, Kano State, Nigeria between the periods of September to December 2005

Sampling points	DO		TDS (mg L^{-1})	Temperature ($^{\circ}\text{C}$)	SO_4^{2-} (mg L^{-1})	NO_3^- (mg L^{-1})	PO_4^{3-} (mg L^{-1})	
	pH	Eh (mV)						
PS	9.23±0.32 ^a	-87.2±1.54 ^a	7.55±0.14 ^c	70.1±8.40 ^a	12.8±0.24 ^a	45.50±0.31 ^a	4.04±0.03 ^a	1.56±0.04 ^a
1 m	8.12±0.21 ^b	-57.2±1.52 ^b	6.67±0.43 ^b	50.0±5.20 ^b	10.2±0.14 ^b	35.20±0.21 ^b	2.41±0.04 ^b	0.91±0.01 ^b
4 m	8.81±0.10 ^c	-46.3±1.34 ^c	5.67±0.54 ^a	40.3±3.24 ^c	8.2±0.14 ^c	22.60±0.21 ^c	1.11±0.02 ^c	0.54±0.02 ^c

The values given in the table above are means of replicate values (n = 75). Within columns, means with different letter(s) are statistically significant ($p < 0.05$). PS: Point Source (point of immediate discharge of effluent into river Challawa), 1 m: 100 meter (after point of discharge of effluent into river Challawa), 4 m: 400 meter (downriver from Point source), Eh = Redox potential, DO = Dissolved Oxygen, TDS = Total Dissolved Oxygen

Table 2: Concentrations of pH, Eh, DO, TDS, temperature, SO_4^{2-} , NO_3^- and PO_4^{3-} in tap water from Challawa, Sharada and Bompai industrial area, Kano State, Nigeria between the periods of September to December 2005

Sampling points	DO		TDS (mg L^{-1})	Temperature ($^{\circ}\text{C}$)	SO_4^{2-} (mg L^{-1})	NO_3^- (mg L^{-1})	PO_4^{3-} (mg L^{-1})	
	pH	Eh (mV)						
TWC	8.45±0.12 ^a	-34.0±1.34 ^a	3.20±0.24 ^a	30.53±1.24 ^a	8.20±0.14 ^a	33.50±1.26 ^a	3.53±0.04 ^a	0.06±0.01 ^a
TWS	8.00±0.11 ^a	-34.3±1.24 ^a	3.24±0.21 ^a	31.21±1.20 ^a	9.12±0.12 ^a	33.23±1.31 ^a	3.47±0.07 ^a	0.06±0.01 ^a
TWB	8.24±0.10 ^a	-35.2±1.34 ^a	3.20±0.23 ^a	30.24±1.26 ^a	8.91±0.13 ^a	33.45±1.21 ^a	3.45±0.05 ^a	0.06±0.02 ^a

The values given in the table above are means of replicate values (n = 75). Within columns, means with different letter(s) are statistically significant ($p < 0.05$). TWC: Tap Water-Challawa, TWS: Tap Water-Sharada, TWB: Tap Water-Bompai, Eh = Redox potential, DO = Dissolved Oxygen, TDS = Total Dissolved Oxygen

Table 3: Concentrations of metals in River Challawa between the periods of September-December 2005

Sampling points	Concentrations (mg L^{-1})						
	Cu	Co	Zn	Mn	Pb	Fe	Cr
PS	0.57±0.05 ^a	0.66±0.04 ^a	7.13±0.56 ^a	2.39±0.14 ^a	2.15±0.04 ^a	10.28±0.31 ^a	0.97±0.31 ^a
1 m	0.44±0.03 ^b	0.51±0.02 ^b	6.45±0.46 ^b	1.83±0.12 ^b	1.36±0.03 ^b	7.12±0.23 ^b	0.65±0.02 ^b
4 m	0.32±0.02 ^c	0.37±0.01 ^c	5.86±0.41 ^c	1.16±0.11 ^c	0.09±0.01 ^c	5.32±0.21 ^c	0.45±0.01 ^c

The values given in the table above are means of replicate values (n = 75). Within columns, means with different letter(s) are statistically significant, $p < 0.05$. PS: Point Source (point of immediate discharge), 1 m: 100 meter (from point of discharge), 4 m: 400 meter (from point of discharge)

Table 4: Concentrations of heavy metals in tap water from Challawa, Sharada and Bompai industrial area, Kano state Nigeria between the periods of September-December, 2005

Sampling points	Concentrations (mg L^{-1})						
	Cu	Co	Zn	Mn	Pb	Fe	Cr
TWC	0.04±0.01 ^a	0.13±0.03 ^a	0.23±0.01 ^a	0.04±0.02 ^a	0.04±0.01 ^a	0.13±0.04 ^a	0.02±0.01 ^a
TWS	0.03±0.01 ^a	0.12±0.04 ^a	0.23±0.02 ^a	0.04±0.02 ^a	0.04±0.03 ^b	0.14±0.04 ^b	0.02±0.02 ^a
TWB	0.04±0.01 ^a	0.12±0.02 ^a	0.23±0.01 ^a	0.04±0.01 ^a	0.04±0.01 ^a	0.14±0.01 ^a	0.02±0.01 ^b

The values given in the table above are means of replicate values (n = 75). Within columns, means with different letter(s) are statistically significant ($p < 0.05$). TWC: Tap Water-Challawa, TWS: Tap Water-Sharada, TWB: Tap Water-Bompai

guidelines, the pH of the river and tap water would not adversely affect its use for domestic purposes (Table 1 and 2). There is also a relationship between pH and Eh as observed from Table 1. As pH values decreased from Point Source (PS) up to a distance of 4 m, Eh values increased. The high value of pH at Point Source (PS) might be attributed to the alkaline wastewater from tannery industries and municipal waste within this area into this point, while the decreased of Eh from point source up to a distance of 4 m might be attributed to dilution and sedimentation of these metals in this river. Levels of DO in River Challawa and tap water from all the sampling points obtained were above limits set by WHO of 3 mg L^{-1} for drinking water.

The dissolved oxygen values were not within the safety limits for maintenance of aquatic life of 5.00 mg L^{-1} (Symonds *et al.*, 1981). The TDS and temperature value were below the WHO and FEPA standards of 50 mg L^{-1} for drinking water. The values of pH, total dissolved solids and temperature decreased with distance from point source up to a distance of about 4 m, while redox potential and dissolved oxygen increased with distance from point source up to distance of about 4 m.

The finding is in line with what is reported (Symonds *et al.*, 1981; Ademoroti, 1996; Rand *et al.*, 1979) that a low DO usually depict a high TDS values. The results of DO and TDS values also emphasized this fact. From Table 1, an increase in TDS corresponded with a decrease in DO. Results of statistical analysis indicated that variations among points were statistically significant in all the parameters determined above ($p < 0.05$) Table 1. While from Table 2, levels of all the parameters were within the WHO and US-EPA safe limits for drinking water. However, variations among locations were not statistically significant in all the parameters determined above ($p < 0.05$) Table 2.

Nitrate toxicity increases the risk of anaemia in infants and pregnant women and formation of carcinogenic nitrosamines (Bush and Meyer, 1982). A nitrate content of more than 100 mg L^{-1} impart bitter taste to water and may cause physiological problem. Drinking water contains more than 50 mg L^{-1} nitrate can cause methamoglobinemia in infant (Uba and Aghogho, 2001). Nitrate causes the overgrowth of algae, other organism and fouls the water system. Epidemiological studies have predicted association between exposures to nitrate and gastric cancer because of the reaction of nitrate with amine in diet. The WHO guideline for domestic water supply states limit of 45 mg L^{-1} for Nitrate levels. The South African guideline for domestic water supply (DAWF, 1996) state 6 mg L^{-1} as safe limit for babies. None of the samples from the river exceeds these limits (Table 1 and 2). Thus, nitrate concentration is not considered to pose a problem for the domestic use of this water. Nitrate in natural waters can be traced back to percolating nitrate from sources such as decaying plant and animal materials, agricultural fertilizer, industrial and sewage waste. For sulphate and phosphate concentrations, none of the water samples from the river and tap water exceeded the 200 mg L^{-1} sulphate WHO maximum permissible level for drinking water that may give rise to Methaemoglobinemia and $5.0 \text{ } \mu\text{g L}^{-1}$ phosphate level (Morrison *et al.*, 2001; DAWF, 1996) that will reduce the likelihood of algae growth and would cause eutrophication in the river. Anion levels in the water samples from River Challawa showed a decrease in concentration with distance from point source up to 4 m. Since Kano state is an agricultural and industrial area, the high levels of nitrate, sulphate and phosphate at Point Source (PS) might be ascribed to introduction of municipal waste, industrial wastewater and runoff from farmland into this point, while the decrease might be related to dilution, sedimentation and depuration due to immense volume of fresh water passing through the river.

Iron concentration was generally very high in all the sample analyzed (Table 2). Although, iron is one of the essential elements in human nutrition, however, when present at elevated concentration in aquatic ecosystems, serious pollution and health problems could result. According to WHO and US-EPA quidline value and maximum contamination levels, concentration value of 0.30 mg L^{-1} Fe in water is acceptable (Radojevic and Bashkin, 1999). Above 0.3 mg L^{-1} , a condition known as heamochromatosis could result. From the results of the analyses, the concentration of the iron in water samples from River Challawa exceeded the regulating limit, indicating severe pollution of the River Challawa by iron. The high level of the dissolved concentration of Fe in the water samples may be attributed to urban and industrial wastes into the water body (Arah, 1985). Wastes management in urban and industrial centers in Nigeria, such as Kano has remained very unsatisfactory. Inflow waters to River Challawa have been found polluted with untreated industrial wastes, which are carelessly discharged, directly or indirectly into the river.

Zinc is equally an essential element in the human diet. Zn deficiency in the diet may be more detrimental to human health than too much of it in the diet (ATSDR, 1994). In aquatic ecosystem Zn is highly toxic to some aquatic organisms. Although Zn is not a human carcinogenic, ingestion of large doses can cause death (ATSDR, 1994). The dissolved concentration of zinc in the water samples from River Challawa exceeded the WHO guideline values of 3.0 mg L^{-1} and maximum contamination levels of 5.0 mg L^{-1} . The high level of dissolved concentration of Zn in the water samples (Table 3) could be traced to urban and industrial wastes from industries located within these areas into the water body (Ezeronye and Ubalu, 2005; Godwin *et al.*, 2004).

The concentration of lead in aquatic environment is risky to life since aquatic organisms used as food are particularly very sensitive to Pb and often retain about a percent of ingested lead which could be taken up by man through food chain (Young and Blevins, 1981). Lead can cause damage to the nervous system and the kidneys and it is a suspected carcinogenic (Radojevic and Bashkin, 1999). Children exposed to high lead levels are particularly at risk. The levels of dissolved concentration of lead in the analyzed water samples from River Challawa (Table 3) showed that the limiting values of WHO and US-EPA, 0.01 and 0.015 mg L⁻¹, respectively were exceeded, indicating contamination of the river body. The present of lead in the river may be attributed to anthropogenic discharge of Pb-laden waste from industrial processes and past uses of various products (example pipes, batteries, paint, petrol, solder and alloy). The dissolved concentration of Mn in the water sample (Table 3) was higher coming third after Zn. A comparison of Mn concentration in surface water with WHO guideline value of 0.02 mg L⁻¹ for water showed that the concentration of Mn in River Challawa is very high and indicating possible pollution.

Concentration of chromium in the river may give cause for concern presently, bio-magnification of it in the river with time may lead to serious condition as chromium is extremely toxic and the primary use of water high in chromium could cause adverse health effects to consumers such as renal disease and cancer (Salido and Jones, 1999). However, Cr limiting levels were exceeded and fell above the 0.05 mg L⁻¹ highest desirable level for chromium in drinking water set by WHO and US-EPA. The high values of Cr might be attributed to the carelessly discharged of tannery and textile effluent from industries located within these areas into the river (Akan *et al.*, 2006, 2007).

Cobalt is an essential element, which could be, introduced anthropogenically into aquatic ecosystems from municipal and industrial wastewater. The toxicity potential of Co is quite low compared to many other heavy metals. However, exposure to very high doses can cause severe health effect. The value of Co exceeded the 0.05 mg L⁻¹ WHO maximum permissible values of cobalt in drinking water and the 0.1 mg L⁻¹ WHO highest desirable values for water meant for the same purpose (Fatoki *et al.*, 2003). The implication of this is that the water from the river may have taste and other aesthetic problems (Fatoki *et al.*, 2003). These results of Cu content in river Challawa was above the WHO limit of 0.05 mg L⁻¹ and Maximum Contaminant Level (MCL) of 0.052 mg L⁻¹ for drinking water (WHO, 1984, Shivkumar and Bikshman, 1995) The concentration of copper content was 5 to 10 times above the permissible limits, indicating possible pollution.

Table 4 shows the mean concentration of heavy metals from tap water within Challawa, Sharada and Bompai industrial areas. From the result levels of heavy metals did not exceed the WHO guideline for drinking water of 0.05 mg L⁻¹ (Cu), 5.0 mg L⁻¹ (Zn), 0.05 mg L⁻¹ (Mn), 0.05 mg L⁻¹ (Pb) 0.3 mg L⁻¹ (Fe) and 0.05 mg L⁻¹ (Cr). Results of analysis of variance (ANOVA and t-test) indicated that variations among points were not statistically significant in all metals except Fe (p<0.05). The low concentrations of these metals might be attributed to the fact that the water are properly treated before supply for domestic used.

Thus the cumulative impact is that heavy metals, dissolved oxygen and phosphate levels in River Challawa are kept high, which might be due to high influxes from industrial wastes, including the immense urban run-off, while pH, Eh, temperature, total dissolved solid, sulphate and nitrate are kept low. While for tap water, the concentrations of the physico-chemical parameter were also kept low.

CONCLUSIONS

Generally, average concentration of heavy metals, DO, phosphate in the water samples were higher, indicating probable contribution of some amount of these parameters by industrial waste, municipal waste and anthropogenic sources to River Challawa while the concentration pH, Eh, nitrate, sulphate, TDS and temperature did not exceed the standard guideline values. However, the

concentration of heavy metals, pH, Eh, DO, TDS, nitrate, sulphate, phosphate and temperature in tap water were within guideline values. The wastewater treatment plants in these industries need to be upgraded to improve their treatment performance.

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