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Physiochemical characterisation and level of potentially toxic metals in surface water around yauri abattoir, north western Nigeria

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Physicochemical and potentially toxic metals statuses of surface water samples collected around the Yauri abattoir were examined. Health risk assessment of the toxicant via ingestion was interpreted by calculating the hazard quotient (HQ). The mean concentration values for total dissolved solid (TDS), total suspended solid (TSS), dissolved oxygen (DO), phosphate, and biochemical oxygen demand (BOD) were 1026.78, 565.22, 5.0, 8.89 and 484.64 mg/L respectively. The values are above those obtained for the control water sample as well as those of international safe limits for water. The values of pH (6.6), sulphate (86.91 mg/L), nitrate (41.45 mg/L) and chemical oxygen demand (COD) (903.30 mg/L) fell within world health organization maximum permissible limits for drinking water. The mean concentrations of Co (6.93 mg/L), Cu (14.45 mg/L), Fe (64.16 mg/L), and Zn (37.14 mg/L) were above both the control and WHO, EU and EPA safe limits for metals in water. On the other hand Cd (11.47 mg/L), Ni (35.49 mg/L), and Pb (41.94 mg/L) had a mean concentration values which are higher than the international standard limits and control water sample. The calculated values of HQ show that Cd, Co, Cu and Ni were of high risk, Fe with a medium and Pb and Zn are of low risk. Correlation coefficients revealed general positive and significant correlations between the pairs of metals in water. The results of this study showed some levels of pollution of the stream water indicating that the activities at the abattoir were contributing to the pollution load of water in the area.

Key words: Yauri, abattoir, toxic metals, physicochemical.

INTRODUCTION

Pollution of the environment by toxic metals even at low levels and their resulting long term cumulative health effects are among the leading health concerns all over the world. They are non-biodegradable, thus persisting for long periods in environmental ecosystems. Environmental pollution has generally become a threat to the existence of humanity and the ecosystem. Some pollution effects may lead to metabolic disorders and undesirable changes which in many cases cause severe injuries and health hazards (Alorge, 1992).

Abattoir can be defined as a premise approved and registered by controlling authorities for hygienic

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slaughtering, inspection, processing, effective preservation and storage of meat products for human consumption. However, meat processing activities in Nigeria are generally carried out in unsuitable buildings and by untrained staff or butchers who are most of the time unaware of sanitary principles (Olanike, 2002).

Abattoir activities may be another source of pollution since human activities such as animal production and meat processing have been reported to influence negatively on soil and natural water composition leading to pollution of the soil, natural water resources and the entire environment (Adesemoye et al., 2006). Activities at the abattoir are aimed at optimizing the recovery of edible portions of the meat processing cycle for human consumption. However, significant quantities of secondary waste materials are also generated during this process. For example, blood, fat, organic and inorganic solids, salts and chemicals added during processing operations are produced as wastes (RMAA, 2010; Steffen and Kirsten, 1989). Various parts of cattle such as muscle, blood, liver, kidney, viscera and hair have been found to contain potentially toxic metals (Kruslin et al., 1999; Jukna et al., 2006). The faeces of livestock (animal manure) consist of undigested food, most of which are: cellulose fibre; undigested protein; excess nitrogen from digested protein; residue from digested fluids; waste mineral matter; worn-out cells from intestinal linings; mucus and bacteria. Other components of undigested food include; foreign matter such as dirt consumed, calcium, magnesium, iron, phosphorous, sodium among others (Ezeoha and Ugwuishiwu, 2011). Abattoir effluent waste water has a complex composition and can be very harmful to the environment. For example, discharge of animal blood into streams would deplete the dissolved oxygen (DO) of the aquatic environment. Improper disposal of paunch manure may exert oxygen demand on the receiving environment or breed large population of decomposers (micro-organisms), some of which may be pathogenic. Also, improper disposal of animal faeces may cause oxygen-depletion in the receiving environment. It could also lead to eutrophication of the receiving system and increase rate of toxins accumulation in biological systems (Nwachukwu et al., 2011).

Mohammed and Musa (2012) reported that the improper disposal of abattoir effluent could lead to transmission of pathogens to human which may cause an outbreak of water borne diseases like diarrhoea, pneumonia, typhoid fever, asthma, wool sorter diseases, respiratory and chest diseases. Studies have shown that *Escherichia coli* infection source was reported to be undercooked beef which has been contaminated in abattoirs with faeces containing the bacterium (Bello and Oyedemi, 2009; Patra et al., 2007). It had also been reported that abattoir activities are responsible for the pollution of surface and underground waters, reduction of air quality as well as quality of health of residents within the surrounding environment (Katarzyna et al., 2009; Odoemelan and Ajunwa, 2008).

The above situations were even more worrisome in the developing countries where research efforts towards monitoring the environment have not been given the desired attention by the stake holders (Adesemoye et al., 2006).

The main purpose of this work therefore, is to study the pollution status of surface water around Yauri abattoir and assess whether the pollution load is sufficient to affect the health of the inhabitants of the areas who depend on this stream as their source of domestic and irrigation water. The results of the study will assist the regulatory bodies monitor more closely the activities at the abattoir as well as create public awareness about the health implications of abattoir activities on the environment and also establish a data bank for future reference.

MATERIALS AND METHODS

The study area

Yauri town in Yauri Local Government Area of Kebbi state, northwestern Nigeria was the study area. It is located southward on the earthen bank of River Niger and falls within latitudes 10° N and 30° N and longitudes 3° W and 6° W of the globe. The area has flat topography with a few elevated areas. It is an extension of the Sokoto plain: dotted with some doom-shaped hills and complemented by a portion of the great River Niger and its numerous tributaries, which gently meanders on the landscape. Yauri abattoir is located some meters from Yauri main market close to Yauri River. Several animals (cows, goats, sheep and cattle) are slaughtered in this abattoir. Normal abattoir operations are carried out every day of the week during morning hours (5 to 11 am) and in the afternoon and evening when the need arise.

Sample collection

Six sampling stations were mapped out along the course of the river in the abattoir area at a distance of 50m from each other. The sampling stations were coded SS_1, SS_2, SS_3, SS_4, SS_5 and SS_6. Six replicate samples were collected from each of these stations and pooled together to obtain a representative sample for that station. Water sample (coded SS_{ctrl}) was collected at a point 60m upstream, and served as a control. Water samples were collected in plastic containers previously cleaned by washing in non-ionic detergent. During sampling, sample bottles were first rinsed with the sampled water three times and then filled to the brim. The samples were labeled and transported to the laboratory, stored in a refrigerator at about 4°C prior to analysis (Akan et al., 2010). A total of forty two samples were collected for the research. The field research is carried out between the months of July and December, 2012.

Sample preparation and analysis

Each sample (100 ml) was transferred into a beaker and 5ml of concentrated HNO_3 was added. The beaker with the content was placed on a hot plate and evaporated down to about 20 ml. The beaker was cooled and another 5 ml of concentrated HNO_3 added. Each beaker was then covered with a watch glass and returned to

Table 1. Mean concentration (mg/L) of potentially toxic metals in the water sample around Yauri Abattoir.

Sampling points	Cd	Co	Cu	Fe	Ni	Pb	Zn
SS_1	22.30±0.03	8.13±2.10	10.21±0.11	50.60±1.30	49.03±2.30	40.51±0.34	62.14±0.04
SS_2	13.10±0.13	3.01±0.70	8.13±2.10	77.02±0.11	18.70±1.00	66.13±0.41	41.07±0.59
SS_3	5.09±0.30	11.68±0.50	19.32±4.40	63.50±0.70	31.61±1.30	38.14±0.03	29.46±1.01
SS_4	8.14±0.21	9.40±0.47	22.31±1.50	48.17±0.50	56.06±0.40	32.10±1.50	31.47±0.09
SS_5	10.07±0.11	7.34±0.09	15.65±2.03	89.11±0.31	30.20±1.60	18.63±1.05	57.72±0.25
SS_6	9.47±0.08	2.03±1.32	11.06±1.30	56.55±2.30	27.31±0.50	56.13±0.01	60.13±0.11
SS_{ctrl}	2.07±1.04	0.63±0.02	5.53±2.30	36.20±2.60	0.59±1.33	22.01±2.01	20.52±0.10
Range	5.09- 22.30	2.03-11.68	10.21-89.11	48.17-89.11	18.70-56.06	18.63-66.13	29.46-62.14
HQ	631.00	641.00	10.85	5.94	49.29	3.88	4.35
EPA*	0.25	23.00	9.00	300.00	52.00	2.5.00	120.00
EU	0.005	N/A	2.00	0.20	0.02	0.01	N/A
WHO	0.003	N/A	2.00	N/A	0.02	0.01	3.00

N/A = Not Available, * = ug/L.

the hot plate for more heating with the addition of few drops of HNO_3 until the solution appeared light coloured and cleared. The walls of the beaker and the watch glass were washed down with distilled water and the sample filtered to remove insoluble materials that could clog the atomizer. The volumes of the samples were made up to the mark (100 ml) with distilled water (Radojevic and Bashkin, 1999). A blank sample was similarly treated so as to give room for blank correction. This was done by transferring 100ml of distilled water into a beaker and digested as described above. Calibration standards were prepared from stock solutions by dilution and were matrix matched the acid concentration of the digested samples. The digested samples were then analyzed for potentially toxic metals using atomic absorption spectrophotometer alpha star model 4 (Chem Tech Analytical) at the Centre for Energy Research and Development of the Obafemi Awolowo University, Ile–Ife, Nigeria. The instrument was operated according to the instrument handbook and data were acquired with Hewlett Packard (HP) Pavilion 3134 software.

The method used for the determination of physicochemical parameters was as described by AOAC (2005) and reported elsewhere (Anon, 1992; Lovell and Colorado, 1983; Ademorati, 1996 Emmanuel and Solomon, 2012).

RESULTS AND DISCUSSION

Potentially toxic metals concentration

Table 1 is presented the mean concentrations (mg/L) of potentially toxic metals in surface water from Yauri. The results show differences in metal concentrations at various sampling stations and their controls. Iron was the most abundant metal recorded. The higher level of Fe recorded within the study area could be related to run-off from rusted metallic roofing sheets on the houses in the area, scrap metal dump sites and the abattoir refuse dump sites. All the metals with the exception of Cd, Ni and Pb were below the international maximum permissible limit (WHO, 2006; EU, 1998).

The sources of cadmium in the urban areas are much less well defined than those of lead, but metal plating and tire enforced with metals were considered the likely common anthropogenic sources of Cd in the street dust through burning of tires and bad roads. Cadmium high mean concentration levels at all the sampling points could be attributed to the above reason and in addition to rural/urban effluents along the river course and atmospheric precipitation. Cadmium is extremely toxic that it could cause adverse health effects to end user when water with high percentage is consumed and it is also toxic to fish and other aquatic organisms.

Lead and Nickel concentrations within the study area is pointed to the fact that naturally, Pb and Ni are distributed in surface waters due to weathering of minerals and atmospheric deposition. Also, Lead and Nickel recorded high values beside the abattoir activities could be related to technical uses, most of which are: electric storage batteries, leachate from sludge containing nickel-cadmium batteries, nickel plate items and emissions from burning of fossil fuels and gasoline which contain high levels of tetraethyl lead (TEL), which is still in use despite, its ban in 2004. Generally, the concentration of metals in water in the study area is higher than the control. It has been reported that potentially toxic metals, reaching excessive levels, can exert serious impact on humans, animals and plants because they are not biodegradable as they are retained indefinitely in the ecological systems and in the food chain (Omprakash et al., 2011).

Physicochemical evaluation

The physicochemical parameters derived from surface water in Yauri around the abattoir are listed in Table 2. It could be seen from the table that the temperature range is from 30.20 to 30.80°C which is lower than 32 to 34°C reported by Osibanjo and Adie (2007). Temperature

Table 2. Mean results of the physicochemical parameters of the abattoir's surface water.

Parameter	SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_{CRTL}	Range
T (°C)	28.40±0.03	31.30±0.10	30.70±2.10	31.80±1.00	30.50±0.09	30.40±1.15	30.40 ±0.11	30.2-30.8
pH	5.30±0.09	7.55±2.11	6.50±1.70	6.50±0.73	6.56±0.91	6.51±0.27	6.70 ±1.42	6.50-6.70
TDS (mg/L)	630.0±3.17	710.0±3.10	2700.0±1.08	1320.0±2.10	260.0±1.00	540.7±2.40	110.0±5.10	250-700
TSS (mg/L)	330.6±1.01	680.3±1.70	1070.0±0.97	720.14±2.14	400.23±0.9	190.0±1.01	12.0±0.09	190-710
DO (mg/L)	3.10±0.00	2.60±0.10	6.00±0.07	8.00±0.00	4.00±0.01	5.00±2.01	5.90±0.02	2.00-9.00
Sulphate (mg/L)	35.064±0.25	41.60±0.89	170.00±0.90	120.00±1.00	95.11±2.05	60.00±5.01	12.00±0.03	38.46-170
Phosphate (mg/L)	8.00±1.00	7.30±0.03	9.10±3.01	16.00±1.09	8.00±0.90	4.70±0.10	2.10±0.03	4.70-16.0
Nitrate (mg/L)	9.40±0.25	31.09±3.20	68.00±1.08	64.06±0.04	9.30±0.10	66.00±4.02	6.00±0.00	9.30-68.0
BOD (mg/L)	350.50±5.01	516.00±0.05	861.70±4.07	812.60±0.90	344.00±0.30	23.00±0.04	12.00±0.08	19.00-861
COD (mg/L)	540.03±1.06	1452.0±5.01	1508.0±9.03	928.0±0.98	444.0±3.04	548.0±1.90	156.0±0.06	444-1508

influences the amount of dissolved oxygen in water which in turn influences the survival of aquatic organisms. The pH ranged from 6.50 to 6.70 with a mean value of 6.60 and falls within WHO standards and compares well with 4.9 to 7.2 reported by Masse and Masse (2002). Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) values ranged from 190.00-710.14 and 250.00-2700.00 mg/L respectively. Their mean values are 565.22 and 1,026.78 mg/L TSS and TDS respectively which, is above WHO maximum permissible limit for TSS (20 mg/L) and TDS (200 mg/L) and also higher than the control. Total suspended solids relatively measures the physical or visual observable dirtiness of a water resource while TDS is an indicator of the degree of dissolved substances, such as metal ions in the water (Efe et al., 2005). Dissolved oxygen (DO) has a range of 2.0 to 9.0mg/L with a mean value of 50 mg/L. This value is higher than international permissible limit of 4 mg/L and also, higher than the control. Low DO may result in anaerobic conditions that cause bad odour. Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) ranges between 19.0-861.7 and 444-1508 mg/L with mean values of 484.63 and 903.3 mg/L respectively. The mean value for BOD is higher than the control and allowable limit of 20 mg/L (WHO, 2006). COD has a mean value lower than the permissible limit of 1000 mg/L. Though, the mean value of COD is lower, some points like SS_2 and SS_3 have values of 1,456 and 1,508 mg/L respectively which are higher than the international standards. Both BOD and COD are indices of organic pollution. BOD is not a specific pollutant indicator, but rather a measure of the amount of oxygen required by bacteria and other microorganisms engaged in stabilizing decomposable organic matter over a specified period of time. A high oxygen demand indicates the potential for developing Dissolved Oxygen sag as the microbiota oxidizes the organic matter in the water. Since nearly all organic compounds are oxidized in the COD test, COD results are always higher than BOD results. This was confirmed in this study with some samples (SS_2 and SS_3) exceeding the value of 1000 mg/L set by WHO.

Nitrate concentration ranges from 9.4 to 68 mg/L with a mean value of 41.45 mg/L. Even though the mean concentration value is low, some points analyzed have values higher than the set standards. It is reported that nitrate concentration above the permissible value by 45 mg/L is dangerous to pregnant women and poses a serious health threat to infants less than three to six months of age because of its ability to cause methaemoglobinaemia (Gelperim et al., 1975). Nitrates have a high potential to migrate into ground water since they are very soluble and do not bind to soil (Punmia and Jain, 1998). Phosphates were at relatively high concentration. All the water samples were above 5mg/L maximum permissible limit except for SS_6 (4.7mg/L). Phosphate enter water ways from human, animal waste and other sources like phosphorus rich bedrock, industrial effluents, fertilizer run-off, laundry and cleaning. Phosphates in water increase the tendency of troublesome algae to grow in the water (Esry et al., 1991). This causes eutrophication or over fertilization as it chokes up the water ways and uses up large amounts of oxygen. Sulphate concentration ranges from 40 to 170 mg/L with a mean value of 86.91 mg/L. This is lower than the maximum permissible limit of 250 mg/L set by WHO but higher than the control value of 12 mg/L. This implies that the activities in the abattoir are contributing to the pollution load of the stream and long term effect may subsequently lead to contamination of the surrounding water body.

Health risk assessment

Health risk assessment is normally based on a quantification of risk level in relation to two types of adverse effects: chronic (non-carcinogenic) and carcinogenic. Chronic risk level estimated was expressed as maximum hazard quotient (HQ_{max}) calculated for a group of evaluated elements and as hazard index (HI) calculated as a sum of HQ of all evaluated elements in every sample ($HI=\Sigma HQ_i$). Characterisation of the chronic risk level consists of threshold effects (tolerance chemical

Table 3. Correlation Matrix for pairs of the analyzed potentially toxic metals in water.

Metals	Cd	Co	Cu	Fe	Ni	Pb	Zn
Cd	1.000						
Co	0.334	1.000					
Cu	0.240	0.113	1.000				
Fe	0.249	-0.042	0.787*	1.000			
Ni	0.552	0.169	0.712	0.797*	1.000		
Pb	0.025	0.073	0.039	0.161	0.391	1.000	
Zn	0.365	0.060	-0.194	0.162	0.011	0.318	1.000

* Correlation is significant at the 0.05 level (2-tailed).

level) and is based on the presumption and manifestation of adverse chronic effects until the threshold, that is, the lifetime daily exposure level tolerated by human beings the so-called reference dose (RfD), is exceeded. The characterisation of carcinogenic risk level consists of a concept of non-threshold effects – that is, no dose is safe and risk-free and each level of exposure can generate a carcinogenic response (USEPA, 1989).

In the present study, health risk from increased concentrations of HM in the surface water was evaluated in relation to its chronic as well as carcinogenic effects, based on the calculation of average daily dose estimates and defined toxicity values for toxic HM (USEPA, 1999) according to the following relationships. The chronic risk level was computed as health risk assessment using CDI and HQ indices. The CDI through water ingestion was calculated using the USEPA (1992) equation below:

$CDI = C \times DI/BW$

Where C, DI and BW represent the concentration of HM in water (microgrammes per litre), average daily intake rate (2 L/ day) and body weight (72 kg), respectively (USEPA 2005).

Conversely, the chronic risk level was calculated (HQ) for non-carcinogenic risk using the following equation by USEPA (1999):

$HQ = CDI/RfD$

Where according to USEPA, the oral toxicity RfD values are 0.0005 mg/kg-day for Cd, 0.0003 mg/kg-day for Co, 0.037 mg/kg-day for Cu, 0.3 mg/kg-day for Fe, 0.02 mg/kg-day for Ni, 0.0036 mg/kg-day for Pb and 0.3 mg/kg-day for Zn, respectively.

The scale of chronic risk level (HQ) based on average daily intake (CDI) and reference dose (milligrammes per kilogramme-day) is classified based on the ratio of CDI/RfD indicating≤ 1 (no risk) if$>1 \leq 5$ (low risk), if$>5 \leq 10$ (medium risk) and if>10 (high risk).

Correlation analysis

One-way analysis of variance with parametric Pearson's correlation between mean potentially toxic metals concentration in the water samples standard statistical methods (Table 3) showed that all the metals were positively correlated except for Fe and Co and Zn and Cu which were negatively correlated. Pb, Cd, and Ni were significantly correlated. The positive and significant correlations between metals in the surface water samples suggest common source.

Conclusions

The results of this study revealed that the physicochemical parameters of the surface water around Yauri abattoir exceeded international recommended safe limits. The mean concentrations of Pb, Ni and Cd were also higher than the regulatory permissible limits. The positive correlations between the pairs of metals in the surface water suggest common anthropogenic source. Generally, the values of the physicochemical parameters and potentially toxic metals were higher in the surface water around the abattoir than the control samples. This implies that the activities at the Yauri abattoir were contributing to the pollution load of the surface water in the area and this has potential for full-blown environmental problems in the near future if not controlled. It is therefore, recommended that the activities of the abattoir should be monitored closely by relevant agencies and constant monitoring of the river water quality is needed to record any alteration in the quality and mitigate outbreak of health disorders and the detrimental impacts on the aquatic ecosystem and through bio-magnifications may enter the food chain thereby affecting the human beings as well.

Conflict of Interest

The authors have not declared any conflict of interest.

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