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Levels of Lead (Pb), Cadmium (Cd) and Cobalt (Co) in Cow Milk from Selected Areas of Zanzibar Island, Tanzania

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Abstract

Milk is one of the very important nutrients of human diet. The presence of toxic elements in milk may threaten the public health. This study reports the levels of Cadmium (Cd), Cobalt (Co) and Lead (Pb) in raw cow's milk collected from different areas of Zanzibar Island during March - May 2016. The samples of raw milk were analyzed by Thermo Scientific-Atomic Absorption Spectrophotometer for quantitative determination of the metals in the matrix. The concentration of Co in this study ranged from ND at Mwanakwerekwe (MK1 and MK2) to a maximum of 0.004 mg/L at Mshelishelini (MS5) and Fuoni (F5) sites with mean concentration of 0.020 ± 0.003 mg/L for all sites. Concentration of Pb ranged between 0.05 - 0.51 mg/L at Fuoni (F7) and Mwanakwerekwe (MK1) respectively, with mean concentration of 0.263 ± 0.031 mg/L for all sites. However, Cd was only detected in one sample collected at Fuoni (F3) with a concentration of 0.001 mg/L. The results revealed that cow's milk is contaminated with toxic metals, particularly Pb which exceeded the WHO maximum permissible level of 0.02 mg/L. The study furthermore sheds light on possible consequences to public health. It is recommended that, stakeholders especially in Zanzibar such as Zanzibar Food and Drug Authorities (ZFDA) and Zanzibar Bureau of Standards (ZBS) as well as researchers, use the findings of this study for policy making, future study plans, formulation of technical strategies to control milk contamination, risk assessment and develop new alternative methods to measure milk contamination even at a low detection limit for the sake of the consumers' welfare before posing any serious effects to their health.

Keywords

Milk, Cobalt, Lead, Cadmium, Zanzibar

1. Introduction

Milk is one of the very important food for supplying nutritious elements; it is a good source of protein, fat, sugar, vitamins and minerals. It is a complex, bioactive substance that promotes growth and development of mammalian infants. Therefore, milk is very important component of human diets that are mainly consumed by children and adults especially elderly people around the whole world [1] [2]. Some chemical residues cause contamination of milk, which results in serious problems and negatively affects the human health. Cow milk contains macro elements such as cadmium (Ca), potassium (K), phosphorous (Ph), and magnesium (M) in addition to sodium (Na), chlorine (Cl) and microelements and even heavy metals. Some heavy metals such as Copper (Cu) and Iron (Fe) are very essential for proper metabolic activity in body of living organisms, while others such as Lead (Pb) and Cadmium (Cd) are non-essential and have no biological role [1] [3].

Cadmium and lead are among the heavy metals that have caused the most concern in terms of adverse effects on human health [4]. They are readily transferred through food chains and are not known to serve any essential biological function [5] [6]. For instance; Ca and Pb have the serious effects on the kidney and nervous system respectively [7] [8] and children have been shown to be more sensitive to Cd and Pb than adults where the effects are cumulative [9]. As a result, the regular absorption of small amounts of certain elements, such as lead, may cause serious effects on the health of growing children, including retardation of mental development such as reading and learning disabilities as well as deficiencies in concentration, adverse effects on kidney function, blood chemistry and the cardiovascular system, as well as hearing degradation [10] [11]. Cobalt (Co) is also toxic metal at higher concentrations which is released into the environment. They originated from dumping industrial wastes in the rivers, as well as due to application of phosphate fertilizers [2].

Environmental pollution has been a major area of concern worldwide. Industrial and agricultural processes have caused an increased concentration of toxicants metals in the environment and as a result being taken up by plants and animals into their systems which cause further distribution of toxicants to the environment [12]. Toxic elements, e.g. cadmium, are absorbed with food and drinking water. Therefore, they can undergo bioaccumulation in products of animal origin and inclusion in the human food chain [13]. Long-term exposure of the human organism to even small doses of heavy metals, resulting from constant presence in a contaminated environment, may be the cause of subclinical changes, often irreversible, revealing themselves after many years, e.g. leukaemia. Milk and its products, e.g. cheeses, kefirs, butter, etc., as basic sources of animal protein, most vitamins and minerals, and common elements of human diet, are at the same time the main source of heavy metals and should be subjected to permanent control of the concentration of those metals [14]. Monitoring studies on products of animal origin (milk, eggs) indicate a considerable variation in the concentration of Cd, Hg, Pb and other heavy metals, from trace levels to amounts exceeding the maximum allowable concentrations many times [13]. In most countries in the world including the whole European Union, limits have been laid down for the level of those metals in food products, and limitations on their emission have been imposed [15] [16].

Therefore, it is important to monitor the level of trace elements in milk, which is a major source of nutrition in childhood consumed with breakfast cereals and as yoghurt or cheese. Absorption of contaminants in food by animals causes accumulation of heavy metals in their milk. Significant amounts of Cd and Pb can be transferred from contaminated soils to plants and grass and finally toxic metal can accumulate in cattle to humans consuming meat and milk as well as through consumption of feeding stuffs and water with toxicants [17]. Due to growing environmental pollution in the world, it is necessary to determine and monitor the levels of heavy metals in milk. This is due to the fact that milk can significantly influence human health as indicated in different reports [2] [3] [18]. This paper, therefore, presents the baseline levels of heavy metals found in cow's milk of Zanzibar Island, Tanzania.

2. Materials and Methods

2.1. Study Area

The study was conducted on Zanzibar Island in Tanzania. Zanzibar lies between latitude 6.16˚S and Longitude 39.2˚E. It is the largest and populated with high land of about 85 km (53 miles) long (north-south) and 30 km (19 miles) wide (east-west). The sampled areas include Mwanakwerekwe, Magogoni, Kwamchina, Mshelishelini and Fuoni. The GPS coordinates (S˚ & E˚) and the characteristics of sampling stations are shown in **Table 1** while the location of sampling areas are shown in **Figure 1**.

Table 1. GPS Coordinates and characteristics of sampling areas.

Location	Coordinate S˚	Coordinate E˚	Characteristics of sampling areas
Mwanakwerekwe	06.17774	039.23298	Main market, busy road, Near dump areas
Magogoni	06.16844	039.23149	Residential area, near to garage
Kwamchina	06.18172	039.22525	Residential area
Mshelishelini	06.19580	039.23403	Residential area
Fuoni	06.19730	039.2654	Residential area

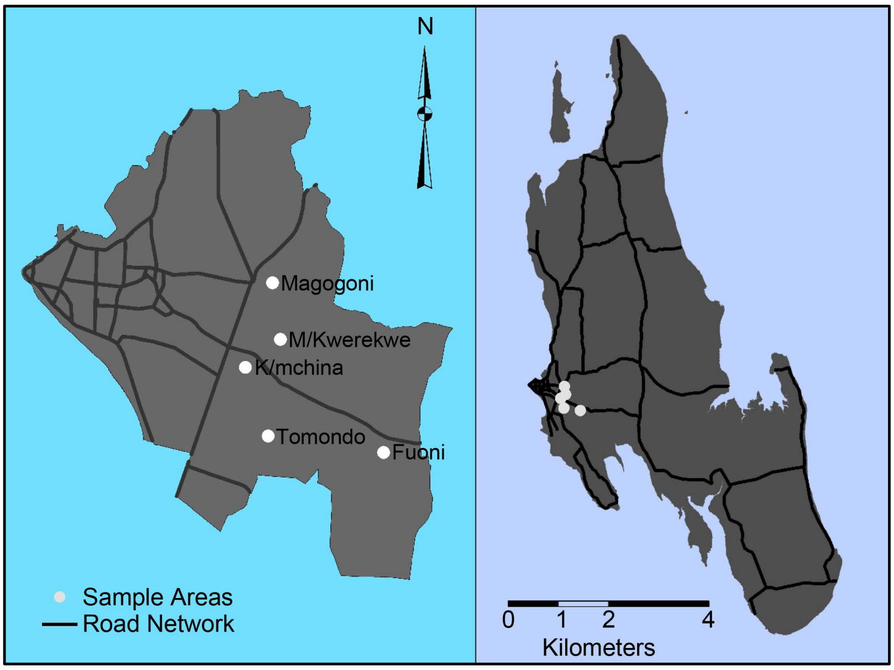

Figure 1. Map of Zanzibar (Unguja Island) showing location of sampling areas.

2.2. Sampling

A total of twenty-five (25) samples of cow's milk were randomly collected from different farmers from March to May 2016 from five selected areas of Zanzibar. Milk sample of 100 ml was collected during milking time at different selected areas. Because the cows in farms have heterogeneous characteristic of animal, age, and weight, the samples are collected directly and carefully into washed plastic bottles. The samples were immediately transported in a cooler with ice packs and then were frozen at −20˚C until analysis.

2.3. Sample Digestion

The milk samples need to be brought into clear solution before analysis by Atomic Absorption Spectroscopy [18]. For this reason, the samples were first digested, dissolved and removed the fat. 5.00 gm of raw cow's milk was treated with 5 ml (65% nitric acid) and 2 ml (30% hydrogen peroxide) and then digested on electric hot plate at 90˚C and the temperature of this mixture was gradually increased to 120˚C until brown fumes appeared, indicating completion of oxidation of organic matter. The organic matrix of milk was destroyed and left the elements in to clear solution. After cooling the clear solution was filtered in 25 ml volumetric flask and completed to the mark with double distilled water. A blank digestion solution was made for comparison in the same way as a real sample. Finally, milk samples were directly analyzed by Thermo scientific Atomic Absorption Spectrophotometer [18].

2.4. Determination of Metal Contents of Each Digested Sample

The Pb, Co & Cd were analyzed with Thermo Scientific Atomic Absorption Spectroscopy with model of (iCE300Series). The instrument was warmed up and then calibrated with standard solutions, a sample aliquot volume of 10 µL of cow milk samples, which was obtained after digestion was injected into graphite tube with the help of an auto-sampler, acetylene was used as a gas, deuterium background correction and a temperature program of the furnace was optimized to obtain the best signal during the atomization process. The instrumental parameters were adjusted according to the manufacturer's recommendation (Unicam-Atomic Absorption Methods Manual 1994). The instrumental conditions for the determination of lead, cadmium and cobalt and detection limits are given in **Table 2**. Concentration of the metal ions present in the sample was determined by reading their absorbance using AAS and comparing it to the respective standard calibration curves (**Figures 2(a)-(c)**). In order to monitor the contamination during the whole procedure of analysis, 5.00 gm of water was treated the same as real milk samples for each batch of analysis as a samples procedural blank.

2.5. Data Analysis

Data were analyzed using one-way analysis of variance (ANOVA) to examine the statistical significance of differences in the mean concentration of heavy metals determined in milk samples. The probability level of P = 0.05 or lower was considered statistically significant.

3. Results and Discussion

3.1. Levels of Toxic Metals in Cow Milk

The concentration of Pb ranged from 0.05 to 0.51 mg/L while the concentration of Co ranged from ND to 0.04 mg/L. Cd was detected in only one station at Fuoni (F3) with the value of 0.001 ng/L. Concentrations of the metals in cow's milk (mg/L) are presented in **Table 3**. The concentration of the metals was in increasing order as Pb > Co > Cd.

Table 2. Instrumentation conditions for determination of Lead, Cadmium and Cobalt in raw cow's milk by Thermo Scientific (Atomic Absorption Spectrophotometer).

Parameter	Pb	Cd	Co
Injection volume	10 µL	10 µL	10 µL
Primary wave length	217 nm	228.8 mn	240.7 nm
Slit width	1 nm	0.5 nm	0.5 nm
Lamp type	HCL	HCL	HCL
Lamp current	10 mA	8 mA	15 mA
Background correction	D_2 lamp	D_2 lamp	D_2 lamp
Atomization temperature	1200˚C	900˚C	1000˚C
Instrument detection limit	0.5 µg/L	3 µg/L	1 µg/L

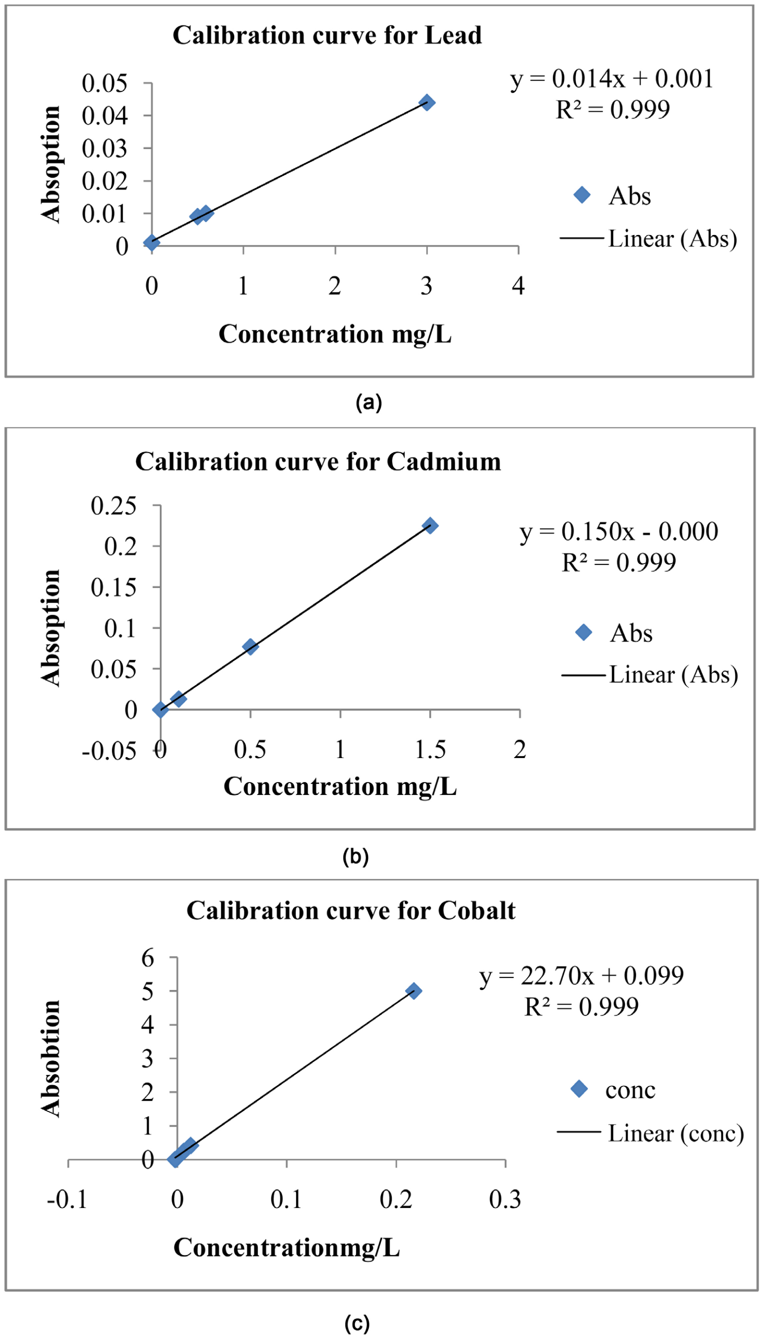

Figure 2. (a) Calibration curve for lead; (b) Calibration curve for cadmium; (c) Calibration curve for cobalt.

3.2. Mean Concentration of Heavy Metals in Cow's Milk

The mean concentrations of Pb and Co were 0.263 ± 0.031 mg/L and 0.020 ± 0.003 mg/L respectively (Table 4). The mean concentration of Pb was relatively higher compared to Co while Cd was below the detection limit except in one sample. However, [3] [19] reports higher Pb levels in Nigeria and Libya respectively, while similar Pb levels in cow milk were reported in Palestine [1]. The mean concentration of Pb in this study was relatively higher than those reported

Table 3. The concentrations of heavy metals in milk.

Sampling sites		Concentration (mg/L)		
Location	Sample code	Pb	Cd	Co
Mwanakwerekwe	MK1	0.51	ND	ND
Mwanakwerekwe	MK2	0.47	ND	ND
Mwanakwerekwe	MK3	0.5	ND	0.01
Mwanakwerekwe	MK4	0.35	ND	0.02
Magogoni	MG1	0.33	ND	0.01
Magogoni	MG2	0.31	ND	0.009
Magogoni	MG3	0.35	ND	0.02
Magogoni	MG4	0.34	ND	0.02
Kwamchina	KC1	0.2	ND	0.01
Kwamchina	KC2	0.19	ND	0.02
Kwamchina	KC3	0.23	ND	0.03
Kwamchina	KC4	0.21	ND	0.01
Kwamchina	KC5	0.19	ND	0.03
Mshelishelini	MS1	0.29	ND	0.01
Mshelishelini	MS2	0.12	ND	0.01
Mshelishelini	MS3	0.17	ND	0.02
Mshelishelini	MS4	0.11	ND	0.03
Mshelishelini	MS5	0.26	ND	0.04
Fuoni	F1	0.12	ND	0.03
Fuoni	F2	0.2	ND	0.03
Fuoni	F3	0.15	0.001	0.03
Fuoni	F4	0.15	ND	0.04
Fuoni	F5	0.16	ND	0.02
Fuoni	F6	0.08	ND	0.03
Fuoni	F7	0.05	ND	0.02

ND = Not Detected.

Table 4. Comparison of heavy metals mean concentration in raw cow's milk with different African Countries (mg/L).

Co	Cd	Lead	Reference	Country
ND	ND	ND	[18]	Ethiopia
0.002	0.068	0.040	[2]	Egypt
NR	0.163	0.550	[3]	Kano (Nigeria)
NR	0.099	0.710	[3]	Zaria (Nigeria)
NR	1.24	3.43	[19]	Libya
0.020	ND	0.263	This study	Zanzibar

NR = Not reported; ND = Not detected.

by [2] in Egypt. The rest of African countries reported higher level of Pb (**Table 4**). Moreover, the mean concentration of Co found in this study of 0.020 ± 0.003 mg/L (**Table 4**) was higher than those reported in the previous study by [2] in Egypt. The variation of heavy metals such as Pb and Co in different sites is likely due to the nature of the location of cows' grazing grounds. The study done by [19] reported about 3.43 mg/L mean concentration of Pb from cows found near busy roads with cars and the areas where the pesticides are used in Libya. The rest of African countries have not reported any value of Co as seen in **Table 4**.

3.3. Distribution of Pb in Sampling Areas

The concentration value of Pb in raw cow milk samples from Mwanakwerekwe ranged between 0.35 - 0.51 and its mean concentration of 0.458 ± 0.074) mg/L. Pb concentration at Magogoni ranged between 0.31 - 0.35 with average of 0.333 ± 0.017 mg/L, while in samples from Kwamchina, concentration of Pb ranged between 0.19 - 0.23 with average of 0.204 ± 0.017 mg/L. Mshelishelini sites, Pb ranged between 0.11 - 0.29 with average of 0.190 ± 0.082 mg/L while that of Fuoni are tamed as indoors had low mean concentration compared to other areas where Pb ranged from 0.05 to 0.20 with 0.130 ± 0.051 mg/L in average (**Table 5**), however all of the values were above the maximum recommended limit of 0.02 mg/L according to [20]. These results showed that concentration of Pb at M/kwerekwe was relatively higher than other areas. This might be contributed by the proximity to the dumpsite and near traffic congestion. Like this study, [21] [43] reported higher levels of Pb at dumpsites from milk and soil samples respectively. Also the Pb concentrations were relatively higher at Magogoni samples, possibly due to the presence of a garage in that area as reported by [22] high in their study of Pb near the garage. This indicates the quality of milk in those areas was questionable. The concentration of Pb at Fuoni was relatively lower; this was possibly due to far distance from point sources that are less exposed to the polluted areas [23]. There was no significant difference ($P > 0.05$) in the mean concentration of Pb between Kwamchina and Mshelishelini (**Figure 3**). However, there was a statistically significant difference ($P = 0.05$) in Pb concentration at the three different sites. For example, there were significant differences in Pb level found in Kwamchina with that of M/Kwerekwe, Magogoni and Fuoni. Similarly, level of Pb at Mshelishelini shows a significant difference with

Table 5. Distribution of lead concentration in (mg/L) in different sampling areas.

Site	Number of samples	Minimum	Maximum	Mean ± std
M/kwerekwe	4	0.35	0.51	0.458 ± 0.074
Magogoni	4	0.31	0.35	0.333 ± 0.017
Kwamchina	5	0.19	0.23	0.204 ± 0.017
Mshelishelini	5	0.11	0.29	0.190 ± 0.082
Fuoni	7	0.05	0.20	0.130 ± 0.051

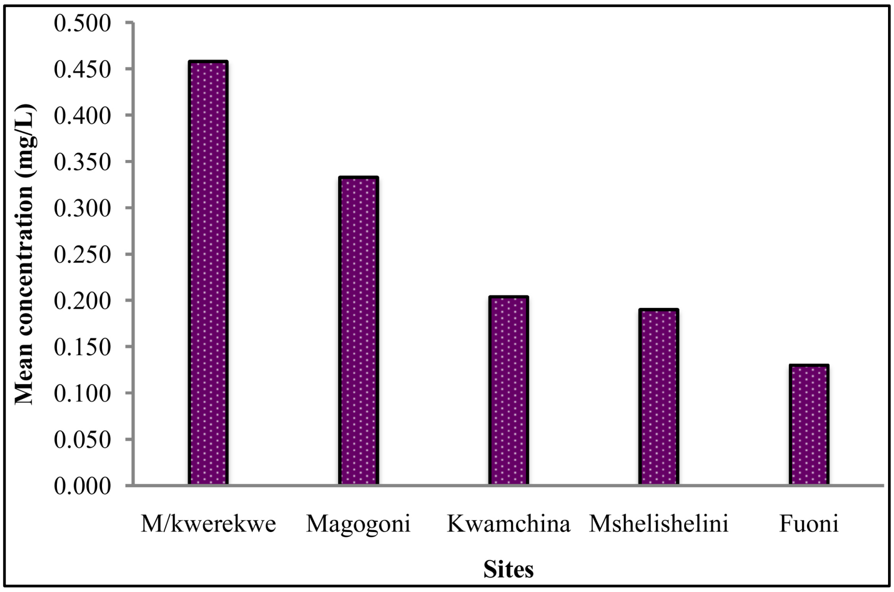

Figure 3. The average concentration of Lead (mg/L) in cow milk from different sampling areas.

M/kwerekwe, Magogoni and Fuoni. Other significant differences were found at Fuoni compared to the rest of the sites (**Figure 3**).

Some European countries reported different levels of the Pb content in milk (mg/L). For instance, [24] reported 0.05 and 0.0018 mg/L for Slovenia and Spain respectively, [25] reported 0.0065 mg/L for Austria, while [26] reported 0.0013 for Italy and [27] reported Pb content from 0.052 to 0.617 mg/L for Romania. Mean lead content in milk from Turkey was 0.0335 mg/L [28], Iran 0.0129 mg/L [29], Mexico 0.03 mg/L [30] and Pakistan from 0.001 to 1.428 mg/L [31]. There are many studies that presented the higher content of Pb in byproducts of milk. For instance, the results of Pb content determination in yoghurt reported by [32] indicated that the product might contain a much higher concentration of this toxic element (4.21 - 24.50 ng/g) than milk (3.35 ng/g). The study by [33] also showed that the content of Pb in yoghurt could depend on production process because samples of drinkable yoghurt contained a higher amount of this element than a pasty one. The concentration of Pb in curd and cheese reported by [30] was comparable to or higher than in milk. It was reported that milk and dairy products represent about 20% of food consumption in Europe, similar to cereals and vegetables [34]. According to [35] food originating from plant, mostly plant roots, is the main source of Pb in human diet. The studies show that this element appears also in the milk of lactating animals fed contaminated grass [35] and consequently goes on to the human diet. The concentration of metals in cow's milk tends to increase with the increasing breastfeeding age because the metals are bioaccumulated. Monitoring of the content of Pb in food is extremely important due to its high toxicity. Accumulation of lead in the human organism leads to a disturbance in the activity of many enzymes and in the functions of structural proteins [14]. The best documented is the effect of Pb^{2+} on the enzymes of the respiratory chain, glycolysis pathway and the synthesis of hem, the effect of which are disturbances in the metabolic transformations of cells, such as regulation of energetic processes, synthesis of proteins and nucleic acids [36]. Pb is a mutagenic element and can cause cancer, disturbances of the haematopoietic system and the central nervous system, and in addition, it has the ability to pass through the placenta [30].

3.4. Distribution of Co in Different Sampling Areas

The mean concentration value of Co in raw cow milk sample at M/kwerekwe was 0.015 ± 0.007 mg/L with a range from ND – 0.02 mg/L, while the mean concentration was 0.015 ± 0.006 mg/L and its range was (0.0009 - 0.02) mg/L for Magogoni. Moreover, average concentration value of Kwamchina was 0.020 ± 0.010 mg/L with concentration range from 0.01 - 0.03 mg/L. The concentration of Mshelishelini range from 0.01 - 0.04 mg/L and its average was 0.022 ± 0.013 mg/L while the average concentration in Fuoni was 0.029 ± 0.007 mg/L where the range was 0.02 - 0.04 mg/L (**Table 6**). However, all of the detected levels of the Co from this study were below the maximum recommended limit of 0.1 mg/L according to [37]. This indicates milk found in sampled areas (**Table 6**) was safe for consumers. The concentration of Co in Fuoni was relatively higher compared to other areas; this was due to the fact that milk samples were collected from indoor cows that normally added supplemental Co in their food for better milk production. [38] reported the addition of 0.02 g and 600 mg of Co in caw's food, which is known as Haifox dairymix and Farmer's superslick respectively. Most rumen and animals require they must add supplemental Cobalt, Cobalt carbonate, Cobalt sulphate, Cobalt chloride and Cobalt glucoheptonate. Comparison between the sites, the findings show that the average concentration of Cobalt is significant difference in level found at Fuoni ($P < 0.05$) with the rest of the sites. This may be due to the fact that the cows from this site are indoors while the rest are randomly fed near dumpsites (**Figure 4**).

3.5. Cadmium

Cadmium is an element that is totally unwanted for the human organism. Its

Table 6. Distribution of Co concentration (mg/L) in different sampling areas.

Site	Number of samples	Minimum	Maximum	Mean ± std
M/kwerekwe	4	ND	0.02	0.015 ± 0.007
Magogoni	4	0.009	0.02	0.015 ± 0.006
Kwamchina	5	0.01	0.03	0.020 ± 0.010
Mshelishelini	5	0.01	0.04	0.022 ± 0.013
Fuoni	7	0.02	0.04	0.029 ± 0.007

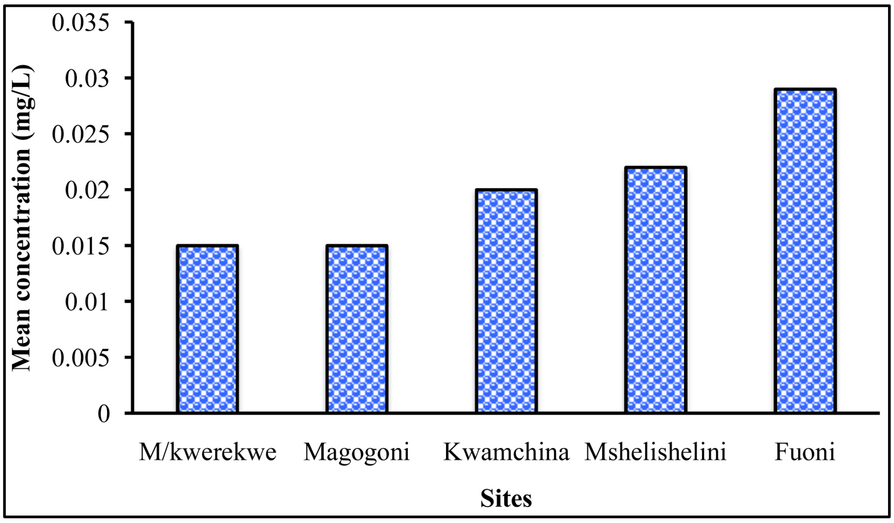

Figure 4. The mean concentration of Cobalt (mg/L) in milk from different sampling areas.

toxic effect is related mainly to its occurrence in the form of free cadmium ions that bind with atoms of sulphur, hydrogen and oxygen, causing disturbances in various metabolic cycles [13]. Cadmium disturbs the metabolism of proteins and the transformation of vitamin B1. In cases of chronic poisoning, it affects the metabolism of calcium and phosphorus compounds, impairs the correct mineralization of bones, and thus increases their fragility. Cadmium is classified among elements with a carcinogenic effect, and its embryotoxic and teratogenic effects are also confirmed [13]. The main source of soil contamination with cadmium is industry, phosphorus fertilizers and wastes. In nature that metal does not occur in a free state, but it is present primarily in sulphide ores of zinc, copper or lead, and also in fossil fuels, e.g. coal. Their mining and processing liberate considerable amounts of cadmium to the atmosphere, hydrosphere and soil [39] from which that toxic metal migrates into food. The concentrations of the toxic heavy metal cadmium in milk samples were too low to be detected by the analytical technique used in this study, except for only one sample from zero grazed cow at Fuoni as shown in **Table 3**, which has a concentration of 0.001 mg/L. Comparable reports from other countries revealed that the concentration found in this study is low than those reported by [1] in Palestine; [3] in Nigeria; [19] in Libya and [2] in Egypt. The tolerable Cd intake established by WHO is 0.06 mg/day for adult women and 0.070 mg/day for adult men. Moreover, Cd content in milk from highly developed countries, such as Italy, Spain and Austria, were at the level of 0.00002 mg/L, 0.00047 mg/L and 0.0007 mg/L, respectively [13]. In turn, the average content of Cd in milk from the territory of Iran was 0.002 mg/L [40], where Pakistan it ranged from 0.001 to 0.053 mg/L [31], and in cow's milk from Saudi Arabia the level of 0.0047 mg/L was determined [41]. According to [33] the content of Cd in milk byproducts such as yoghurts varies from 2.5 to 12.4 ng/g, depending on the yogurt kind. [32] obtained Cd concentrations in the range from 1.36 to 2.22 ng/g and they were even lower than those determined for plain milk. The non-detectable level of cadmium in this study indicates the milk samples were not contaminated with cadmium or are below detection limit. It is gratifying to know that the sample milk from the different indoor cows, as well as cows from contaminated and polluted areas in this study, are free from cadmium contamination and therefore were safe for consumers.

3.6. Implication of Heavy Metals to Public Health

In this study, three heavy metals were analyzed Pb, Co and Cd but only the concentration of Pb in all samples exceeded permissible concentration 0.02 mg/L as recommended by WHO. Pb is one of the limited classes of elements that can be described as very toxic. There is no exposure level below which Pb appears to be safe [22]. High level of Pb in milk is particularly of great concern especially due to the fact that most infants and children who are uniquely susceptible to the effect of Pb consume milk. **Figure 5** shows distribution of Pb seems to be higher in all sites as compared to the Co. This indicates that cow's milk contains a high concentration of Pb in all areas. Pb accumulates in the body's organs such as brain, may trigger poisoning or even death. The gastrointestinal tract, kidneys, and central nervous system are also affected by the presence of Pb. Children exposed to Pb are at risk of impaired development, lower IQ, shortened attention span, hyperactivity, and mental deterioration, children with under the age of six being at more risk. Adults usually experience decreased reaction time, loss of memory, nausea, and weakness of the joints when exposed to Pb [42]. Human beings need to be free from chemical contaminants and diseases although this phenomenon is difficult due to the nature of our environment, there is a need to improve the areas of animals grazing by keeping them free from contamination, dumpsites, busy road and other factors, which contribute cow milk to be polluted [13] [22] [43]. The cow milk from this study was free from Cd, therefore was safe for consumers although samples from Fuoni found more contaminated

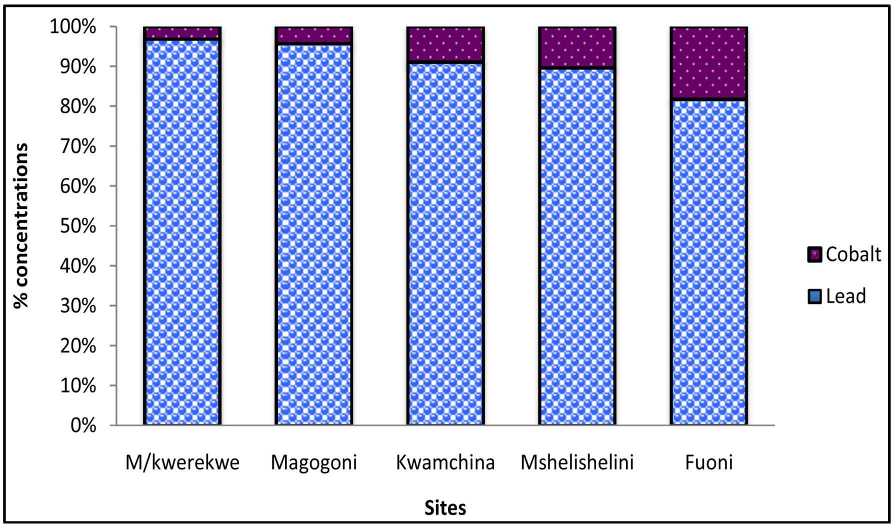

Figure 5. The distribution of heavy metals in different sampling areas.

by Co compared to the rest of the area as indicated in **Figure 5**. Therefore, this study will help regulating agencies and health dealers to increase the round clock monitoring of cow's milk in different areas in order to avoid the risk of their adverse effect on the consumers' health.

4. Conclusions and Recommendations

The baseline concentrations of Pb, Cd and Co in cow's milk from selected areas of Zanzibar were established in this study. The concentration of Co in this study ranged from ND to a maximum of 0.004 mg/L with mean concentration of 0.020 ± 0.003 mg/L for all sites. Concentration of Pb ranged between 0.05 - 0.51 mg/L with mean concentration of 0.263 ± 0.031 mg/L for all sites while Cd was only detected in one sample with the concentration of 0.001 mg/L. The results of this study showed that cow's milk is less contaminated with toxic metals for Co and Cd and may not cause any threats to the consumers. Levels of Pb found in this study exceeded permissible concentration of 0.02 mg/L as proposed by WHO. The causes of milk samples contamination in this study were possibly due to traffic congestion, presence of cows near garages and dumpsites and maybe through addition of chemicals in animal food. In light of the findings, it might be concluded that the levels of concentration of heavy metals (Co and Cd) in the sample milk of Zanzibar were tolerable since were below WHO recommended maximum limits. However, Pb concentration was above WHO recommended maximum limit and may pose serious health effects to the consumers. Therefore the following recommendations are forwarded.

1) Since the study was based in the West district only, the concentration of heavy metals in cow's milk from other parts of Zanzibar such as North, South and Central parts of Unguja Island as well as Pemba Island should be monitored.

2) Nowadays environmental pollution due to different human activities is considered to be at high level and in one way or another may cause a serious effect on human health by conserving contaminated foods such as milk. Therefore, monitoring of the levels of heavy metals in cow's milk should be encouraged.

3) The findings of this study should be used by stakeholders especially in Zanzibar such as Zanzibar Food and Drug Authorities (ZFDA) and Zanzibar Bureau of Standards (ZBS) for policy making for the sake of the consumers' welfare before posing any serious effects to their health.

4) The data should be shared with many parties especially government agencies, private sectors, researchers and other stakeholders for the future study plan, formulation of technical strategies to control milk contamination, risk assessment and develop new alternative methods to measure milk contamination even at a low detection limit.

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Conflicts of Interest

The authors declare no conflict of interest.

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Appendices

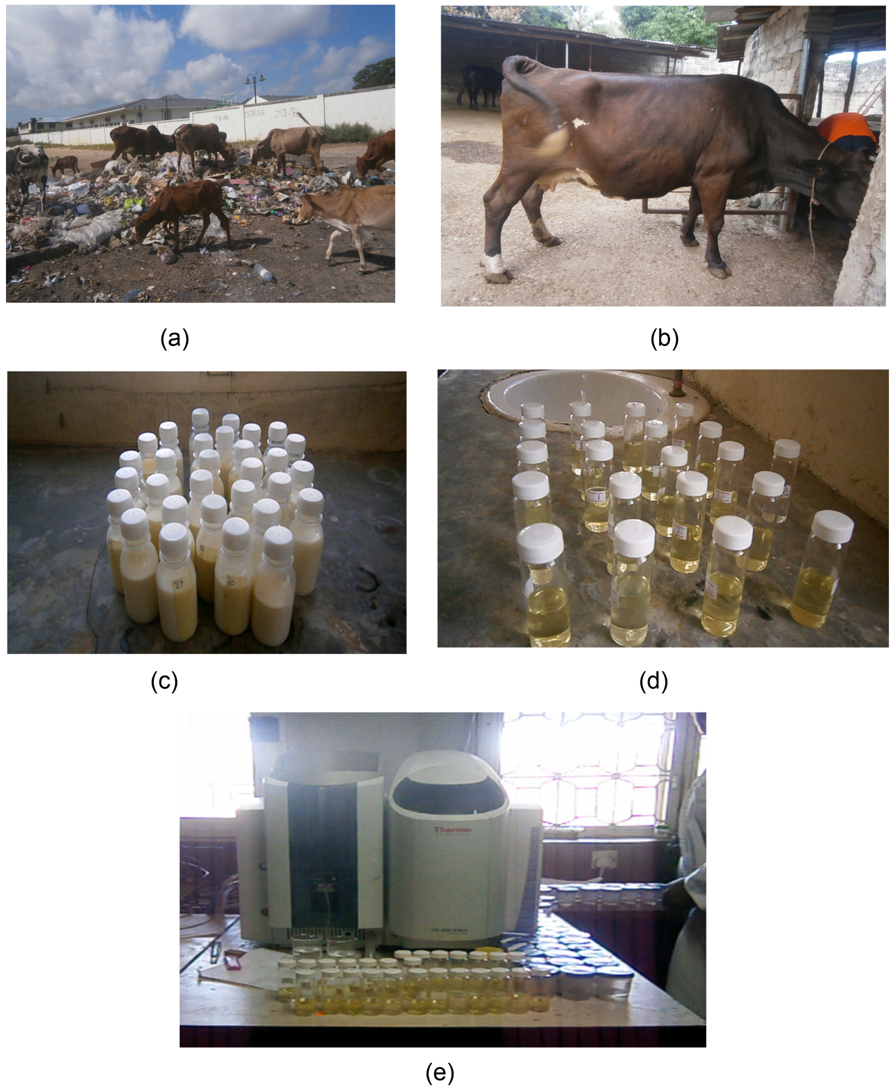

Figure A1. (a) Sample of cattle at Mwanakwerekwe site; (b) Indoor cattle at Fuoni site; (c) Milk samples before digestion; (d) Milk samples after digestion; (e) Analysis of samples by atomic absorption spectrophotometer.