EVALUATION OF HEAVY METALS IN PACKAGED DRINKING WATER WITHIN MINNA METROPOLIS

By

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NIGER STATE, NIGERIA.

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A PROJECT SUBMITTED TO THE
DEPARTMENT OF CHEMICAL ENGINEERING
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IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR IN ENGINEERING (B.ENG) DEGREE IN CHEMICAL ENGINEERING

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DECLARATION

I hereby declare that, this project, "EVALUATION OF HEAVY METALS IN PACKAGED DRINKING WATER WITHIN MINNA METROPOLIS" is an original work of mine under the supervision of Professor K.R Onifade. That it has not been presented anywhere for the award of any degree in any institution. All information derived from published work of others has been duly acknowledged.

Sanusi Abayomi Taiwo	1/12/2011
Student Name	Date

CERTIFICATION

This is to certify that this project "EVALUATION OF HEAVY METALS IN PACKAGED DRINKING WATER WITHIN THE MINNA METROPOLIS" is the original work of Sanusi Abayomi Taiwo of the department of Chemical Engineering in the partial fulfillment for the award of Bachelor degree (B.eng) in the school of Engineering and Engineering Technology, Federal University of Technology, Minna, Niger State.

Professor K.R. Onifade
Project Supervisor

Date

Dr. M.O. Edoga
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Date

22/02/2012

External examiner

Date

DEDICATION

This project is dedicated to Almighty God for his sustenance, benevolence and guidance throughout my academic pursuit.

ACKNOWLDGEMENT

My acknowledgement goes first and foremost to God Almighty who has sustained me throughout my academic pursuit.

My parents Mr and Mrs Sanusi who toiled to ensure that I realize my dream. I am grateful to them for their moral and financial support as well as their prayers. I equally owe a lot of gratitude to my siblings Tunde and Bunmi Sanusi for words of encouragement and for their prayers.

I will ever remain grateful to my supervisor professor K.R Onifade for all the time and energy expelled in seeing that the project is completed. Words alone cannot tell but may God reward you in a million fold.

I equally acknowledge all my able lecturers for the knowledge they have impacted on me in one way or the other. May God continue to fill you all with his knowledge.

Last but not the least; I acknowledge all my friends and classmates for the wonderful time we spent together in the course of our studies. May Almighty God crown our efforts with success.

ABSTRACT

The concentration levels of selected metals, (Cu, Fe, Ni, Pb and Mn) were determined in five packaged water samples collected in Minna metropolis, Niger State, Nigeria. Using Atomic Absorption Spectrophotometer (AAS) Sample A (Mutunci) has the highest amount of Lead (0.1 mg/l) and sample D(Golden Age) has the highest amount of Copper(0.02 mg/l) and so on. However the results for all the packaged water showed that, their mean levels are within the standard values of heavy metals in packaged drinking water in Nigeria.

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Chapter One

1.0 INTRODUCTION

Water is the major constituent of living matter. It is an essential requirement for the maintenance of a healthy community. Pure water does not exist in nature. The contamination of water is directly related to the degree of contamination of our environment. Rainwater collects impurities while passing through the air. Streams and rivers collect impurities from surface run off and through the discharge of sewage and industrial effluents. These are carried to the rivers, lakes or reservoirs that supply our drinking water (Skeat, 1969). All of the chemicals generated by man will eventually end up in our water supplies. These dangerous products from industry, agriculture and other human activities enter the rivers, lakes, and underground water, and can contaminate our drinking water with heavy metals (Adegoke, 2009).

Heavy metals are sometimes called “trace elements”. They are the metallic elements of the periodic table. Heavy metals have become of particular interest in recent decades within the framework of environmental investigation. This has without doubt been due to the fact that highly sensitive analytical procedures are available for determining and detecting metal content with high precision. Because of the importance of the heavy metal ions on human metabolism, trace heavy metal analysis is an important part of public health studies. Some transition metals at trace levels in our metabolism are important for good health. Heavy metals normally occurring in nature are not harmful to our environment, because they are only present in very small amounts. However, if the levels of these metals are higher than the levels for healthy life, the roles of these metals change to a negative dimension. The main sources of the heavy metal ions directly are food and water (Skeat, 1969).

Drinking water is also an important source for heavy metals for humans. The levels of heavy tal ions in drinking water are generally at µg/l. Organizations like the World Health ganization and federal agencies like the Federal Environmental Protection Agency (FEPA), e National Agency for food and drug administration and control (NAFDAC) e.t.c, recommend nits for heavy metals in drinking water. Random checks are usually carried out by officials om federal and state Environmental Protection Agencies to ensure the guidelines initially given o the operators of various water factories are strictly adhered to (Amoo, 2007).

1.1 Aim

This research project aims to evaluate heavy metals in packaged drinking water through the following objectives:

- To carry out qualitative analysis on various brands of packaged water.
- To determine the extent of contamination if any, identify the substandard products and make possible recommendations.

1.2 Scope of Project

The scope of work will involve carrying out the following:

- Carrying out analysis on the samples and assessing the following parameters Iron, Zinc, Lead, Copper, Manganese.

1.3 Justification

The production of portable water has increase drastically in recent years as well its consumption. Since this packaged portable water is consumed by virtually everyone on a daily basis, it is important to evaluate the level of heavy metals in it.

This research project is justifiable because:

a) It will help to enlighten consumers about the purity of packaged water being consumed.

b) It will help the producers of this portable water to increase the quality of portable water being produced and possibly adopt a better way of water treatment.

c) The expected results will also call the attention of regulatory agencies to water brands that do not meet their standards, so that they can monitor and control their activities.

Chapter Two

2.0 LITERATURE REVIEW

2.1 Water

ater is the one of the most common substances known; Water is the only substance that occurs ordinary temperatures in all three states of matter, that is, as a solid, a liquid, and a gas. As a olid, or ice, as clouds formed of ice crystals. It occurs in the liquid state as rain clouds formed of vater droplets, and on vegetation as dew; in addition, it covers three-quarters of the surface of he earth in the form of swamps, lakes, rivers, and oceans. As gas, or water vapor, it occurs as fog, steam, and clouds. Atmospheric vapor is measured in terms of relative humidity, which is the ratio of the quantity of vapor actually present to the greatest amount possible at a given temperature.

Water is an odorless, tasteless, colorless liquid. It is a chemical compound of hydrogen and oxygen, and is formed when two atoms of hydrogen combines chemically with one atom of oxygen to form a molecule of water represented as H_2O . Water has a freezing point of 0 °C (32 °F) and a boiling point of 100 °C (212 °F) (SON, 1984). In water treatment process, there are few steps involve to ensure water cleanliness. The first step includes is flocculation process which combines small particles into larger particles. Then, the water will be filtered to remove all particles from it. After that, water undergoes ion exchange process to remove any inorganic contaminants. Then, adsorption of water in which to remove organic contaminants, unwanted coloring and taste-and-color causing compound take place. Lastly, chlorination process is carried out to disinfect the water (Skeat, 1969).

2.1.1 Definition of Portable Water

Portable water can be defined as the water delivered to the consumer that can be safely used for drinking, cooking and washing (Ademoroti, 1996). The public health aspects are of such importance and the complexity that the health authority having jurisdiction in the community now reviews, inspects, samples, monitors, and evaluate on a continuing basis the water supplies to the community using constantly updated drinking water standards, such public health helps to guarantee a continuous supply of water maintained within safe limits.

Hence, it could be summarized that portable water must meet the physical, chemical, bacteriological parameters when supplied by an approved source (De Zuane, 1996). Man over the years has tried to set drinking water standard. The first drinking water standards were issued about 400 years ago. Also in 1958, the first publication of international drinking water standards was issued by the World Health Organization. These publications were revised in the 1963 and 1968 and later on in 1983.

In 1996, the new W.H.O International Standards were released and that has been the basis of most national standards (W.H.O, 1996). It should be emphatically noted that the most important parameter for drinking water quality in the microbiological quality, that is the bacteria and vital content (De Zuane, 1996).

2.1.2 The Atomic Absorption Spectrophotometer.

The Atomic Absorption Spectrometer (AAS) makes use of absorption spectrometry to assess the concentration of an analyte in a sample. It requires standards with known analyte content to establish the relation between the measured absorbance and the analyte concentration and relies therefore on Beer-Lambert Law. In short, the electrons of the atoms in the atomizer can be promoted to higher orbital (excited state) for a short period of time (nanoseconds) by absorbing a defined quantity of energy (radiation of a given wavelength). This amount of energy, i.e., wavelength, is specific to a particular electron transition in a particular element. In general, each wavelength corresponds to only one element, and the width of an absorption line is only of the order of a few picometers (pm), which gives the technique its elemental selectivity. The radiation flux without a sample and with a sample in the atomizer is measured using a detector, and the ratio between the two values (the absorbance) is converted to analyte concentration or mass using Beer-Lambert Law. The processes in a flame AAS include the following stages:

Desolvation (drying) – the solvent is evaporated and the dry sample Nano-particles remain;

porization (transfer to the gaseous phase) – the solid particles are converted into gaseous lecules;

omization – the molecules are dissociated into free atoms;

nization – depending on the ionization potential of the analyte atoms and the energy available a particular flame, atoms might be in part converted to gaseous ions.

istilled water (free from contaminants) is placed in a test tube and the AAS pneumatic ebulizer is placed in it to aspirate the water to clear the system. After this has been done, the prepared standard solutions (2 ppm & 4 ppm) of the parameter to be measured are placed in the nebulizer to calibrate the AAS.

2.1.3 Parameters of Interest

2.1.3.1 Iron

Iron is found in most raw waters and trace amounts can usually be found in distribution systems where the water has been in contact with iron pipes (Wahab, 2008). Iron can be present in numerous forms. Iron is not harmful on aesthetic ground; it can impart a bitter taste if present in large amounts, making the water unpalatable. It can give rise to iron bacteria which in turn cause further deterioration on the quality of the water by producing slimes or objectionable odors. The maximum amount of Iron permissible in drinking water according to the SON standard is 0.3 mg/l.

2.1.3.2 Zinc

Zinc in its elemental form is a bluish-white metal. Zinc is found naturally at low concentrations in many rocks and soils principally as sulphide ores and to a lesser degree as carbonates. Zinc can be introduced into water naturally by erosion of minerals from rocks and soil (WHO, 1996), however since zinc ores are only slightly soluble in water. Zinc is only dissolved at relatively low concentrations. High natural levels of zinc in water are usually associated with higher concentrations of other metals such as lead and cadmium. Most zinc is introduced into water by artificial pathways such as by-products of steel production or coal-fired power stations, or from the burning of waste materials. Zinc is also used in some fertilizers that may leach into groundwater. Older galvanized metal pipes and well cribbings were coated with zinc that may be dissolved by soft, acidic waters (WHO, 1996). Zinc is an essential nutrient for body growth and development; however drinking water containing high levels of zinc can lead to stomach cramps, nausea and vomiting. The SON standard for zinc in drinking water is 3 mg/l.

2.1.3.3 Lead

Lead (Pb) is very toxic and common heavy metals. It gets into the water from the corrosion of plumbing materials. Sources including paint, mining wasters, incinerator ash, automobile exhaust, water from Pb pipes and solder that are used to join Cu pipes, in fittings and faucets are made from brass. Intake of Pb causes delay in physical or mental development for infants and children. Whereby for adults, it may cause damage to kidneys, brain, and nervous system, learning and synthesizing protein, nerves, red blood cells ability, cancer, hypertension and hyperactivity (Jennings *et al*, 1996). The maximum amount of lead permissible in drinking water according to the SON standard is 0.01 mg/l.

2.1.3.4 Copper

Water turns blue-green in color as the corroded copper inside of the pipes mix together with the water as a precipitate. Copper in a very high quantity is toxic and may cause vomiting, diarrhea and loss of strength. In a long term, the toxicity can cause liver damage, kidney failure and ultimately death while the short term effect is gastrointestinal distress (Madsen *et al*, 1990). The maximum amount of copper permissible in drinking water according to the SON standard is 1 mg/l.

2.1.3.5 Manganese

Manganese is one of the most abundant metals on the earth's surface, making up approximately 0.1 % of the earth's crust. Manganese is not found naturally in its pure (elemental) form, but is a component of over 100 minerals (ATSDR, 2000).It is a mineral that naturally occurs in rocks and soil and is a normal constituent of the human diet. It exists in well water as a naturally occurring groundwater mineral, but may also be present due to underground pollution sources.

nganese may become noticeable in tap water at concentrations greater than 0.05 milligrams liter of water (mg/l) by imparting a color, odor, or taste to the water. However, health effects m manganese are not a concern until concentrations are approximately 10 times higher. posure to high concentrations of manganese over the course of years has been associated with xicity to the nervous system, producing a syndrome that resembles Parkinsonism. This type of fect may be more likely to occur in the elderly. The new manganese standard is set low enough ensure that the potential nervous system effect will not occur; even in those SON may be more nsitive. Manganese is unlikely to produce other types of toxicity such as cancer or reproductive amage (USEPA, 2004). The SON standard for manganese is 0.2 mg/l

2.2 Chemical Characteristics of Water

2.2.1 Alkalinity

Alkalinity is almost due to the bicarbonate, carbonate and hydroxide ions in the water. Usually in association with calcium, magnesium, sodium and potassium. Analysis often quotes alkalinity in terms of $CACO_3$ instead of carbonate and bicarbonate content. This is a convenient form of expression. Alkalinity can exist in water below the neutral point of pH value 7.0 because of the relationship between alkalinity, carbon dioxide and pH value, in simplest form of the relationship bicarbonate alkalinity is in equilibrium with carbon dioxide in the water between pH values 4.6 and 8.3.

2.2.2 Acidity

Water with a pH of less than 7 is said to be acidic. When fossil fuels are burned, sulfur, nitrogen, and carbon combine with oxygen to form compounds known as oxides. When these oxides are released into the air, they react chemically with atmospheric water vapor, forming sulfuric acid, nitric acid, and carbonic acid, respectively. These acid-containing water vapors—commonly known as acid rain—enter the water cycle and can subsequently harm the biological quality of soils, lakes, and streams which serve as sources of water for water treatment plants (WTP).

2.2.3 Hardness

Hardness may be considered a physical or chemical parameter of water; it represents the total concentration of calcium and magnesium ions reported as calcium carbonate. Other metallic ions may be present in specific cases in such a considerable amount as to require inclusion in hardness reporting quantity. Therefore it can also be defined as the sum of polyvalent cations present in the analyzed water. Originally, hardness was examined and evaluated in raw water sampling as an indicator of water quality in terms of precipitating soap. In this measurement calcium and magnesium are the major precipitating ions followed by iron and aluminum with manganese strontium, Zinc and hydrogen ions as additional chemicals that may precipitate soap (De zuane, 1996).

Chapter Three

3.0 METHODOLOGY

3.1 Sampling Techniques

The process of collecting samples is very important and must be handled with great care to obtain accurate result. Therefore sampling is very vital in the analysis since no matter how accurate the analysis is, if samples are not well expressed the results will be misleading.

All samples should be carried out on the samples immediately they are collected. The faster the analysis the more likely the result will be a fair representation of the sample.

Five samples of different brands of packaged water were collected in all. The samples were obtained from different locations. Each sample was given an alphabet to identify it.

3.1.1 Sampling Point

This refers to the different locations where the samples were collected as follows:

The five samples collected here are as follows:

MUTUNCI –A , Elwaziri estate

EVERSHINE – B, collected at Gidan kwano

HAPPY DAYS – C, Tunga

GOLDEN AGE - D, Maitumbi

BAKUMA –E, Bosso

Table 3.1: List of Reagents and Materials

S/N	REAGENTS/MATERIALS	SOURCE	SPECIFICATION
1	Five packaged water Samples	Minna Metropolis	100 ml each
2	Distilled water	Soil science, F.U.T.Minna	100 ml
3	Heater	Soil science, F.U.T.Minna	
4	Filter Paper	Soil science, F.U.T.Minna	
5	Conical flask and Test tube	Soil science, F.U.T.Minna	
6	Beakers	Central Engineering Research Laboratory	50 ml
7	Measuring Cylinder	Soil science, F.U.T.Minna	100 ml
8	Gas cylinders	Central Engineering Research Laboratory	Acetylene Gas cylinders
9	Concentrated HNO_3	Soil Science, F.U.T.Minna	1:1 Nitric Acid
10	Stock solutions for Preparation of Standards	Central Engineering Research Laboratory	For Mn, Pb, Cu, Fe, and Zn
11	Foil Paper	Soil Science , F.U.T.Minna	

3.2 Method of Analysis

The test for the concentration of heavy metals in water samples began with the rigorous digestion of the samples to ensure all organo-metallic bonds were broken. This was done by acidifying the entire sample with 1:1 Nitric Acid solution to make the pH less than 2.

100 ml of the water sample was measured and poured into a conical flask; pebbles (broken bottle) were added. 5 ml of HNO_3 was added to the sample in the fume cupboard. The mixture was heated in an oven until some of the solution vaporized. The remaining solution after vaporization was poured into a measuring cylinder. The solution was usually between 10-20 ml. If it was not up to 100 ml, distilled water was added to make up the volume. The solution was then filtered into another measuring cylinder. The volume was recorded; finally distilled water was added to make the volume up to 100 ml.

Standard solutions of each of the parameters to be determined were prepared from stock solutions whose concentration is usually 1000 mg/l. Serial dilution of the stock solution were made into smaller concentrations e.g. 1 ppm, 2 ppm. e.t.c.

For example to prepare a 2 ppm standard solution in a 50 ml bottle, The following formula was used

$$C_1V_1 = C_2V_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

C_1= concentration of stock solution (mg/l) V_1= volume of stock solution (ml)

C_2= concentration of desired standard solution (mg/l). V_2= volume of standard solution (ml)

C_1 is usually 1000 mg/l

$$1000 \times V_1 = 2 \times 50 \quad \ldots\ldots\ldots\ldots\ldots 3.2$$

and $V_1 = 0.1$ ml. 3.3

This means to prepare a 2 ppm solution, 0.1 ml of the stock solution must be pipette into a 50 ml conical flask and filled to the brim with distilled water.

3.2.1 Determination of Iron

The AAS was first zeroed using distill water after which it was calibrated using 2 ppm & 4 ppm standard solutions of iron. The parameter to be measured, which in this case is iron was selected using the AAS button. The nebulizer was placed in the First sample A1, it was aspirated up and splashed into the oxygen-acetylene flame. The concentration of iron in the sample was a measure of the amount of radiation (of particular wavelength) absorbed by the free iron ions from the cathode lamp of that particular metal ion, which in this case is iron. Distilled water was placed again in the nebulizer to clear the previous sample after which the sample A2 was introduced. This was repeated for samples B, C and D.

3.2.2 Determination of Zinc

The same procedure used for iron ion was followed. The difference were in the selection of Zn on the AAS and the use of standard solution of zinc for the calibration.

3.2.3 Determination of Lead

The same procedure used for iron ion was followed. The difference were in the selection of Pb on the AAS and the use of standard solution of lead for the calibration.

3.2.4 Determination of Copper

The same procedure used for iron ion was followed. The difference were in the selection of Cu on the AAS and the use of standard solution of copper for the calibration.

3.2.5 Determination of Manganese

The same procedure used for iron ion was followed. The difference was in the selection of Mn on the AAS and the use of standard solution of Manganese for the calibration.

Chapter Four

4.0 RESULTS AND DISCUSSION

4.1 Results

Table 4.1 Atomic Absorption Spectrophotometer Test Result

SAMPLES	1st& 2nd analyzes	PARAMETERS (mg/l)				
		Zn^{2+}	Fe^{2+}	Mn^{2+}	Cu^{2+}	Pb^{2+}
A	A1	0.00	0.20	0.08	0.01	0.01
	A2	0.00	0.20	0.06	0.01	0.01
	AVERAGE	0.00	0.20	0.07	0.01	0.01
B	B1	0.00	0.19	0.10	0.00	0.00
	B2	0.00	0.21	0.10	0.00	0.00
	AVERAGE	0.00	0.20	0.10	0.00	0.00
C	C1	0.00	0.10	0.08	0.00	0.00
	C2	0.00	0.10	0.08	0.00	0.00
	AVERAGE	0.00	0.10	0.08	0.00	0.00
D	D1	0.00	0.20	0.10	0.02	0.00
	D2	0.00	0.20	0.10	0.02	0.00
	AVERAGE	0.00	0.20	0.10	0.02	0.00
E	E1	0.00	0.09	0.07	0.00	0.00
	E2	0.00	0.11	0.07	0.00	0.00

A= Mutunci B= Evershine C= Happy Days D= Golden Age E= Bakuma

The results obtained from laboratory analysis are tabulated as shown in Table 4.1. All results obtained are compared with standard organization of Nigeria's standards which are the acceptable standard for drinking water within the country.

4.2 Discussion of Results

4.2.1 Iron

The concentration of Iron in the water samples were found to fall within the range of 0.1-0.2 mg/l which is below the SON standard of 0.3 mg/l. Hence it complies with the SON standard for iron in drinking water.

4.2.2 Zinc

All the samples of packaged water were found to be free from zinc. Far below SON standard of 3 mg/l for zinc in drinking water.

4.2.3 Lead

The concentrations of lead in all the samples were 0.00 mg/l except for sample A that has a concentration of 0.01 mg/l which is the maximum permissible limit when compared with the SON standard of 0.01 mg/ L for lead in drinking water. Due to the toxicity of lead, it is generally advisable to keep the concentration far below the standard to reduce the chances of an epidemic disease from the consumption of such water,

4.2.4 Copper

The copper content in the water samples were found to be zero except in sample A with a copper content of 0.01 mg/l which is below the SON standard of 1 mg/l.

4.2.5 Manganese

The concentration of manganese in the water samples was found to comply with the SON standard of 0.2 mg/l. It is in the range of 0.07-0.1 mg/l . Though manganese concentration in the water samples are below the standard, but at concentrations as low as 0.02 mg/l, Manganese can form coatings on water pipes that may later slough off as a black precipitate (Bean, 1974).

Infants between the ages of 1-6 months also stand at risk if any of the above sample is used to prepare their food as their daily intake of manganese is not to exceed 3 μg/l daily (Ljung and Vahter , 2007)

Chapter Five

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the analysis carried out on the five commonly consumed packaged water in Minna, it was noticed that the average level of the contents of zinc, copper, lead, iron and manganese in the five samples of packaged water are within the permissible limits allowed by SON for heavy metals in drinking water.

In conclusion, it can be stated that the packaged water within Minna metropolis are safe for drinking and other domestic purposes.

5.2 Recommendations

Based on each of the metals

Iron

Iron should not be used in the construction of the water treatment plant because Iron corrodes in the presence of water and oxygen, thus impacting a reddish brown color in water and also increasing the Iron content of water.

Zinc

Alloys are mostly coated with zinc to make them corrosion resistant. Such alloys should be avoided in the construction of vessels to be used for water purification and treatment. Since the concentration of zinc in the water samples is 0, it shows there is no possibility of over exposure to zinc.

Lead

Lead is mostly found in water that are transported through lead pipes and it is advisable that lead pipes should not be used in design/construction of water treatment plants.

Copper

Copper pipes should not be used in the design and construction of water treatment plants, because copper contaminates water transported through it.

Manganese

Proper disposal of manganese containing substances like batteries, glass, fireworks etc after use. The use of potassium permanganate as an oxidant for cleaning, bleaching, and disinfection purposes should be reduced in water treatment plants

Other recommendations:

1. Stringent penalties should be introduced so as discourage illegal producers operating from hiding.
2. Inventory of retailers should be kept, approved retailers should be assigned to distribute their products and they should be warned not to allow these products to over stay their expiring date which is normally within two months.

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APPENDIX

PPM	Part per million
SON	Standard organization of Nigeria
NAFDAC	National Agency for Food, Drug Administration and Control
WHO	World Health Organization
FEPA	Federal Environmental Protection Agency
AAS	Atomic Absorption Spectrophotometer
EDTA	Ethylene Diamine tetra-acetic acid
Cu	Copper
Pb	Lead
Mn	Manganese
Fe	Iron
Zn	Zinc.
ATSDR	Agency for Toxic Substances and Disease Registry