KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF SCIENCE, FACULTY OF BIOSCIENCES

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

LEVELS OF ALUMINUM IN SOME SELECTED FOOD PRODUCTS

BY

JULIET OFOSUAH

JUNE 2017

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THIS DISSERTATION IS PRESENTED TO THE DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF M.Sc. DEGREE IN FOOD QUALITY MANAGEMENT

BY

JULIET OFOSUAH

JUNE, 2017

DECLARATION

I do hereby declare that this research paper is my own work towards MSC Food Quality Management Degree and that it contains no material previously published by another person or material which has been accepted for the award of any other degree of any other University, except where due acknowledgement has been made in the text.

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ABSTRACT

Aluminum, due to its inherent properties in making of packaging materials for food and that is beverage cans and foils etc. has been noted to be negatively impacting health. High levels of aluminum intake have been suspected to cause several neurodegenerative disorders which include Alzheimer disease and Parkinson disease. In this research, samples of bread, canned drink and sachet water were sampled from a study area and the level of aluminum was determined using the Atomic Absorption Spectrometer. The sample solution on injection is aspirated into a flame to be atomized and vaporized. These are then absorbed by a source element and following the Beer's law, absorption is directly proportional to the concentration of atomic vapor in the flame, the concentration of the analyte was estimated. This study showed that six of the water samples had aluminum levels <0.001µg /L and the remaining samples to be ranging from 0.005 – 0.031µg/L, the canned drinks had aluminum levels within 0.62 - 0.175 mg/mL and the bread samples had aluminum content between 0.603-5.33 mg/kg. The values for drinking water fell within acceptable ranges 0.05 to 0.2 mg/L in all, it has been established that the provisional tolerable weekly intake from all sources is 1 mg/kg of body weight. This gives the indication that, though the aluminum finds its way into the various food by different ways, the final product still remains safe for consumption. The challenge may present itself when there is accumulation beyond tolerable limits due to frequency and quantity of consumed sources of contamination.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Aluminum, as a metal, is widely distributed in the earth's crust. It is always found to be bounded to other elements especially oxygen, silicon or fluorine due to its high reactivity as a metal. Compounds containing aluminum are often in the soil, minerals, rocks and clay. As a silvery-white and light weight metal, only purification of some compounds can a pure aluminum be obtained. It has been actively used in several industries due to its inherent properties. In the making of packaging materials (beverage cans and foil), utensils (pots and pans), siding and roofing, airplanes, aluminum has been used. Also, aluminum has been a part of some industrial chemical products like aluminum sulphate and consumer products like cosmetics, antiperspirants, food additives, antacids and astringents (ATSDR, 2008).

Aluminum, though not needed by the human body, is one of the elements that human beings are exposed to in relatively large amounts. As some minerals, vitamins and trace elements have been established to positively support human health, aluminum has been noted to be negatively impacting health. When there are increased levels of aluminum concentration have been made, there is to its consequent higher risk of several neurodegenerative disorders which may include Alzheimer's disease, Parkinson' disease and dialysis encephalopathy (Berthon, 1996). It has also been documented that the buildup of aluminum in tissues as brain, liver, kidney and bone is able to cause renal failure and subsequent system toxicity Wills *et al.(*1993), The consumption of unprocessed foods like fresh fruits and vegetables and processed food with aluminum based additives as well as the use of medication with aluminum based compounds expose humans to aluminum. Air, water and soil which are contaminated could be also expose human to aluminum intake (ATSDR, 2008).

As discussions have been initiated concerning a possible correlation between the high exposure of people to aluminum and its consequent potential of developing the Alzheimer's disease, consciousness of many on how exposed, by any means, they are to aluminum have been raised since there could be a chance of them suffering the consequence of its toxicity.

1.2 PROBLEM STATEMENT

Aluminum due to its much abundance may through several ways get into the human system. There is the global deliberation on the possible positive correlation between aluminum consumption and the causation of Alzheimer's disease (Mercoda, 2014).

In Ghana, there have not been documented works that determined the levels of aluminum concentration in foods including drinking water, drinks and breads. Though research findings are not yet conclusive, a knowledge of the levels of contamination will be a good approach to start with as there is the quest to always assure the quality and safety of food for consumption.

1.3 JUSTIFICATION

Though there is no conclusion on whether there is a direct causative effect of ingestion of aluminum through foods resulting in any disease yet, there will still be a need to consciously prevent a lot of its intake as much as possible. A determination of the levels in foods within this sphere will present the stands of consumers which will incite a need to critically examine ways to reduce them (if they are extremely high) so as to prevent any potential harmful effect.

In the research and constant deliberation to assess the levels of aluminum in foods and its potential causation of diseases, information gathered on the table of discussion are mostly without data from Ghana. No epidemiological study has been conducted in Ghana which will contribute to the discussion so as to reach a conclusion in this study. Without a bases such as a foreknowledge of the content levels in food products within this sphere, an epidemiological study could not be initiated to assess conditions as they stand within this area.

1.4 OBJECTIVE

To determine the aluminum content in selected sachet water, canned cola drinks and breads

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 EXPOSURE TO ALUMINUM

Aluminum, the third most predominant element and the most copious metal on the surface of the earth and its discovery is sometimes credited to Hans Oversted of Denmark who worked on it in 1825 (Frank *et al.,* 2009). Naturally, there is ample exposure of Human beings to aluminum through food, water and air (Hans, 2014). The natural occurrence of aluminum in the environment is as a result of anthropogenic activities (Tchounwou, *et al.*, 2012). As a metal, aluminum finds use in the consumables and appliances, food packaging and cookware industries. As a compound, it comes with a variety of uses and purposes, some of which include; water treatment, papermaking, fire retardant, fillers, food additives, colours and pharmaceuticals, just to mention a few (Coursey *et al.*, 2015).

Factors such as, temperature, pH, dissolved organic carbon, alkalinity, and anion concentration differentiate one aluminum compound from the other. The most common form of aluminum compound that occurs in water are hydroxides. The chemistry of aluminum in water however becomes more complicated as a result of the organic and inorganic ligands that compete with the hydroxide ion (OH-) (Atkinson *et al.,*) The use of aluminum in the pharmaceutical, cosmetics and food industries makes it readily available for ingestion (Barthelmy D, 2008). Some city water purification systems use aluminum sulphate to clarify the drinking water which lead to unknowingly ingesting aluminum in this manner (Yen-Koo, 1992).

It however has a relatively low bioavailability and has for many years failed to be considered as a health threat. A likely association between aluminum consumption and the contraction of Alzheimer's disease was suggested by animal experiments conducted in 1965 (Bilkei-Gorzo, A *2012).* In this report, aluminum salts which were injected into the brain of a rabbit was observed to have caused certain alterations in the brain tissues. Increasing aluminum concentrations are also reported to have been in the brain of patients who died of Alzheimer. However, many other studies have not been able to establish the basis to confidently connect aluminum consumption as a direct or indirect (where it may cause pathological changes in the studied species) cause of the disease (Gorzo A 2012).

The serum of neuropathic patients is reported to have increased concentrations of aluminum. This heightened the awareness on the toxicity of aluminum to man (Pettersen *et al.*, 1990). The link between neurological diseases of patients on dialysis and an increased aluminum intake was first established by Alfrey (1984). These findings augmented the concerns on the increased oral intake of aluminum. Further studies by the same author also reported aluminum to be an endocrine disruptor in the female Nile Tilapia.

Undoubtedly, food has been the key medium of aluminum intake into humans. The exact source may however be considered as primary or secondary. The natural aluminum content of food which comes as a result of the geologic environment of the food raw materials during growth and considered practically unavoidable is the primary aluminum source. In addition to the primary content there are possible forms of aluminum contamination which include the contamination resulting from contacts of food with aluminum items, additives, veterinary drugs, fertilizers and the air, all these are considered as a secondary source of aluminum. Experts consequently agree that, aluminum exposure is something to worry about. Numerous studies have keenly analyzed the likelihood of aluminum to initiate harmful effects in humans through breathing, oral or skin contact. Studies conducted on laboratory animals support a large number of such findings. The findings of studies that focused on exposure due to occupational hazards as well as studies in animals propose that, after inhalation exposure, the nervous system and the lungs may be the most sensitive targets of toxicity. Workers exposed to aluminum dust or fumes have been observed to have respiratory effects; specifically, impaired lung function and fibrosis. This observation has however not been consistently carried out across studies and it is thus probable that, these effects could have taken place due to the co-exposure to other toxic compounds other than aluminum. Granulomatous lesions are some effects on the respiratory system detected in guinea pigs, rats and hamsters. Concerns have been raised on the fact that, these effects can be attributed to overload of dust instead of describing it as a direct effect of aluminum in lung tissue (Domingo, 1993).

In occupational studies, most workers were noted to be exposed to aluminum in its dust form (McIntyre powder), fumes (during welding) or both (in pot rooms). These have given indications suggesting the possible positive correlation between chronic aluminum exposure and a resultant subclinical neurological effects. These effects including distortions in neurobehavioral tests for psychomotor and cognitive performance as well as an increased incidence of subjective neurological symptom (Chattopadhyay,2010) But for some special cases, exposure during breathing has not been linked with overt indicators of neurotoxicity. Failure to appropriately characterize aluminum exposure remains as the shared drawback of these work-related exposure studies. The inadequacy of the available animal respiratory studies to monitor and analyse the potential for induced by aluminum is due to the fact that, the histology of the brain and its weight happen to be the end points of neurology that were examined (Liukkonen-Lilja and Piepponen, 1992). EPA (1990) and Barnes *et al.* (1988), report that, numerous intake over-the counter products such as antacids and buffered aspirin contain some amount of aluminum; clinical studies have been done on people who have normal renal function and its health effects. Based on historical use, there is the assumption that, the intake of these products at their recommended dose make them safe in healthy individuals. Also, another assumption made is that products are labelled safe with their generally regarded as safe (GRAS) status of food additives containing aluminum. There is; however, some indication that, the prolonged usage of medications containing aluminum in some healthy individuals, can result in adverse health effect (Eicher *et al.*, 2004).

The exposure levels of aluminum which pose minimal risks to humans (MRLs) have been set. An MRL is simply an estimation of the daily exposure of humans to a substance that is not likely to have an appreciable risk of adverse effects (non-carcinogenic) over a specified duration of exposure (Eldred, 1994) For an MRL to be derived, it involves the availability of reliable and sufficient data which are either used to determine the target organ(s) of effect or the detection of the most sensitive health effect(s) for a specific period of time within a given path of exposure. In MRLs, only noncancerous health effects are considered and not carcinogenic effects. They can also be derived although no appropriate methodology for the development of MRLs for dermal exposure, thus for acute, intermediate, and chronic duration exposures for inhalation and oral routes and there exists Methods to derive these levels have been established; however, there still exists some uncertainties that are associated with these techniques (EPA, 1990; Barnes *et al.*, 1988).

2.2 ALUMINUM IN FOOD PACKAGING

Approximately ninety-five percent (95%) of the cans used for packaging drinks in Ghana are made from aluminum. The outstanding properties of aluminum have extensively influenced its use in the packaging industry. Notable among the advantages of using aluminum is its cost effectiveness and ease of recycling, this has thus caused authorities as well as individuals to overlook the negative health implications of aluminum. Ongoing studies on the utilization of aluminum as a packaging material will pave a way for the industry to find alternate materials to replace aluminum canning as a method of packaging products so as to reduce the threats it poses to consumers. Alternate packaging materials such as paper and plastic if used can help reduce the negative health implications of aluminum canning on food packaging. Scientists have formulated two hypotheses in their quest to unravel the impact of aluminum as packaging material. These hypotheses, dating as far back as the 1980s are the catalysts of research on aluminum toxicity. The first one states that, the concentration of aluminum in drinking water may be a cause of Alzeimer’s disease (AD) (Martyn *et al.,* 1989; Vogt, 1986). The EHC 194 commissioned a technical report by the International Programme on Chemical Safety (1997), a joint venture of the United Nations Environmental Programme, International Labour Organization, and the World Health Organization, and then derived the hypothesized association from the following six points:

1. The experimental initiation of neurofibrillary changes in animals and consequent neurological impairment perusal to the administration of aluminum salts.
2. The elevation of aluminum levels in the grey matter of the brains of people suffering from Alzheimer's disease (AD).
3. The detection of aluminum in the amyloid core of the histological markers of Alzheimer's disease (AD) (the plaques and tangles).

4. Epidemiological studies that depict a relationship between aluminum intake in drinking water and the prevalence of Alzheimer's disease (AD).
5. A reported reduction in rate of Alzheimer's disease (AD) advancement in one's oral vs. placebo controlled trial of desferrioxamine, a trivalent ion chelator
6. The reported interactions of aluminum with beta-amyloid protein (the major component of plaques) and tau (the major component of tangles).

The second hypothesis that was made was the possibility of using silica as a protective factor for Alzheimer's disease (AD) for which Birchall and Chappell, (1989) mitigated a factor against aluminum toxicity and build-up in the brain. Majority of the epidemiological studies examining the relationship between the concentration of aluminum in drinking water and the rates of contraction of Alzheimer's disease (AD) have been carried out around the world, including countries such as Norway, France, Switzerland, UK and Canada.

Due to its widespread distribution in the environment, aluminum can be found in all stuffs with the concentrations being higher in plant than animal products. In general, all foodstuffs contain aluminum with concentrations higher in foods of plant origin than that of animal origin. Studies have been conducted on the concentration of aluminum in food assortments in various European countries and the USA (Greger, 1992)

2.3 THE BENEFITS OF ALUMINUM AND ITS PACKAGING

For more than 60 years the aluminum can has been used for canning processed foods. According to the Australian Aluminum Council, a notable advantage of aluminum as a packaging material is its light weight. Other advantages include thermal conduction, ability to be recycled, flexibility and impermeability (www.reducepackaging.com).

aluminum is considered relatively very light having a density of 2.70g/cubic cm (compared with iron used in steel 7.86g/cubic cm). Its lightness also cuts down the cost of transportation. aluminum is a good barrier against impurities contained in liquid and air. This quality makes food, cosmetic and packaged drugs safe for consumption. The heat conduction ability of aluminum is about 2.4 times greater than that of iron. The combined effects of the thinness of aluminum packaging materials and their high conductivity make heat loss and gain very effective and efficient. It is therefore good for cooking and refrigerating food and water. aluminum is highly ductile and malleable. aluminum can be completely recycled with great efficiency as 5% of the original energy requirement is required for recycling. aluminum drinking cans are the most widely recycled packaging materials in the world as stated by the Australian Aluminum Council, (1999).

In terms of recycling, barrier and transportation cost the Australian Aluminum Council, (1999), has indicated that aluminum is an excellent packaging material. Aluminum products also have a long shelf life. Futura Industries, is an aluminum manufacturing company that delivers "customized, aluminum extrusion services" from start-to-finish.

Corrosion does not occur in aluminum. Protection from corrosion is offered naturally by its own oxide film, it can however be further improved by anodizing or by the use of other finishing techniques. Complex shapes with aluminum are obtainable through extruded sections in one-piece without necessarily using mechanical joining methods. This method strengthens the parts causing it to be less likely to leak or even loosen over a period of time. Several techniques are employed in finishing aluminum, such as powder coatings, anodizing, electroplating and painting. aluminum packages come in many different forms and as well allows for a multitude of coatings and finishing options as stated by Futura industries.

aluminum is one of the cheapest costing packaging materials. In a manufacturer's decision making concerning which material to use for packaging, aluminum stands out. (www.futuraindustries-customaluminum.com).

2.4 OTHER SOURCES OF ALUMINUM

2.4.1 Aluminum as Cookware

aluminum is popularly used for production of cookware, mainly because it is light in weight and relatively cheap. For many years, several studies have indicated that the use of aluminum cookware may cause headache, indigestion and colitis. These claims have now been confirmed to be true. It becomes more evident when acid-containing food are cooked in the aluminum wares. Further toxicity is caused when steel utensils are used together with the aluminum utensils.

2.4.2 Aluminum Cans

Beer and soft drink cans are produced solely from aluminum. These beverages are usually highly acidic hence, a single beer or cola drink if consumed daily can lead to aluminum toxicity in susceptible individuals with of time.

2.4.3 Pharmaceutical products - Antacids

Large quantities of aluminum hydroxide can be found in antacids, such as Mylanta, Maalox, Riopan, Gaviscon, Rolaids, Alka Seltzer among others. aluminum is also found in Aspirin compounds, such as Ascriptin. aluminum is used in these drugs to serve as an anticholinesterase agent which neutralizes the purgative effect of the magnesium hydroxide present in the antacids. There are aluminum free antacids, such as a type of Riopan as well as Tums.

2.4.4 Drying Agents

Sodium silicon-aluminate is a fine powder used as a drying agent in cocoa, salt and a host of other products. It is also usually used in baking powders.

2.4.5 Cosmetics

Aluminum is used as a base for a variety of cosmetics and paints.

2.4.6 Aluminum as Anti-Perspirants

Aluminum chlorohydrate or other aluminum compounds are also used in anti-perspirants to prevent sweating. Deodorants, on the other hand just release smell but are unable to prevent sweating.

2.4.7 Water supply

In most municipal water supply systems, aluminum is added to the drinking water to serve as a flocculant; thereby increasing the rate of sedimentation of dirt. Moreover, some water supplies in towns and cities may naturally have significant aluminum content.

2.5 HEALTH RISK OF ALUMINIUM EXPOSURE

2.5.1 Metabolism of aluminum

Aluminum is available in substantial amounts in water, food and air, but a huge portion of it is not absorbed by the body. The rate of aluminum absorption is dependent upon a host of factors including parathyroid hormone concentration, as well as the amount of minerals competing with the aluminum for absorption. The higher the amount of other minerals the lower the absorption rate of aluminum. When aluminum is consumed orally the brain and few other vital organs are the sites of accumulation. The only aluminum compound that is not absorbed is aluminum phosphate.

2.5.1.1 Retention and Excretion

Aluminum is retained largely in the liver, lungs, thyroid, brain and bones. The amount of aluminum in most tissues does not rise with age. In lung and brain tissues the levels increase significantly as one gets older.

Most of the aluminum absorbed from the gut bind with plasma proteins. Substantial evidence shows that there is uninterrupted penetration of aluminum through the blood-brain barrier. Breast milk is one of the mediums for aluminum excretion, the major ones being urine and faeces. The excretion of majority of aluminum through faeces is the reason why most aluminum is not absorbed.

2.5.2 Health Risk

The hazard of aluminum as a packaging material should be considered, regardless of the convincing argument with regards to its advantages. Although the association between aluminum and Alzeimer's diseases is not sufficiently proven, more evidence exists indicating a link between aluminum and the disease than there is evidence for the other environmental factors. Large volume of studies with regards to aluminum intake indicating that it is carried by a carrier protein called transferrin through the blood-brain barrier into the brain. Transferrin is a predominantly iro-transporting protein. Transferrin in the brain is mainly located in portion containing large amount of transferring. These areas are susceptible to
Alzheimer's disease. (Gillette-Guyonnet, *et al.*,2006).

Reports by researchers indicate a direct link between concentration of aluminum in the brain and Alzheimer's disease. Despite the fact that aluminum is located in diverse places, it is only through food packaging that makes it have direct contact with our foods. Scholars are of the belief that aluminum cans used for packaging release large amount of the element into the drinks. Researchers have reported that, the cans used for the canning of carbonated and noncarbonated beverages, like colas and fruit drinks, leach significant amounts of aluminum into the beverage. Other means of aluminum rise in our bodies include baking soda, cooking ware and drinking water among others. Given the rate at which aluminum is preferentially used for packaging worldwide, its concentration in the blood is expected to increase even further.

The National Institute of Nutrition, (NIN, 2010), being a part of the Indian Council of Medical Research, has concluded that, the consumption of aluminum compounds from diverse sources has drastically increased and has led to the production of prejudicial effects on human health. The use of aluminum cookware in the preparation of acidic foods such as tomatoes is very risky as it causes the metal to be leached out. Besides Alzheimer's disease, aluminum is also linked to many other chronic diseases such as Parkinson's disease and dementia which cause non-reversible damage to the human body due to the toxic levels of aluminum consumption.

According to the aluminum Can Group (1997), old age exacerbates the toxic effect of aluminum on the consumer. The older the consumer the higher the tendency of acquiring Alzheimer's disease. Coatings are used to minimize the contact between aluminum and food during packaging. The coatings, however, come with their own problems too. To ensure that, beverages in aluminum cans are safe, protective polymer coating is applied to the inner part of aluminum beverage cans to prevent the acids and salts from coming into contact with the metal itself which helps prolong the storage life. Thereby, protecting the food and consumer from the aluminum. The polymer coating material used can however cause other damages to one's health. Absolute Astronomy (2008), has indicated that, the internal coating aluminum cans the aluminum protection from corrosion by the beverage. In spite of the coating, trace amounts of the metal aluminum can be dissolve into the beverage. The quantity of the aluminum that dissolves depends on parameters like temperature, and content of the liquid. A typical compound usually used in the internal coating is epoxy resin. Absolute Astronomy has shown that the epoxy resin is poisonous when it enters the gastrointestinal tract. The plastic material used together with the aluminum in lining the surface of the can is another source of health hazard.

According to studies on aluminum materials by Bruno and Carter (1998), the intake of epoxy resin could be dangerous to many organs and tissues. It causes great damage to the eye, mouth, oesophagus, lungs, stomach, and nose, among others. Following exposure, damage to gastrointestinal tissues continues for weeks, which may result in death. Usually the only way to treat the extensive damage is removal of parts of the organ. The studies have come to the conclusion that in addition to the damaging effect of direct aluminum intake, the aluminum lining used for packaging is also harmful.

There is a large amount of data on human studies concerning aluminum poisoning. Most of the data were however, obtained in people with poor kidney function and who underwent intravenous haemodialysis for a long period of time, with dialysis fluid contaminated with aluminum but it was also documented that generalizing findings from such studies to an entire population becomes problematic (Klosterkotter, 1960).

Dialysis encephalopathy is a chronic neurological syndrome, characterized by the gradual loss of motor, speech, and cognitive functions. It can also occur as a result of the accumulation of aluminum in the brain of human. People who drink water containing high concentration of aluminum have been noted to have high risk of Alzeimer's disease. On the contrary, although tea and antacid contain very high levels of aluminum, there is no significant link has been found to exist between intake of tea or the use of antacid and the risk of Alzheimer's disease as compared to drinking water. Despite this, aluminum from these sources (thus tea and antacid) is poorly absorbed. Over the years, aluminum has been found not to be a causative agent of Alzheimer's disease with respect to the available data. However, it is possible that it may be play a role in the disease development (Pigott *et al.,* 1981).

Several reports have been made about the causes of skeletal changes in adult and children with normal kidney function who have been treated with long-term antacid for gastrointestinal diseases. Secondary to hypophosphatemia and phosphate depletion caused by aluminum impairing phosphorus absorption by binding with dietary phosphorus, are these skeletal effects. In mammals there is huge amount of database on the oral toxicity of aluminum. The nervous system has been found to be the most affected system in the body. Other damaging effects related to aluminum exposure include; erythropoietin and damage to erythrocytes in rats exposed to 230 mg Al/kg/day and higher, higher susceptibility to infection in mouse dams exposed to 155 mg Al/kg/day, reduced pup body weight gain in mice and rats exposed to 103 mg Al/kg/day and delays in pup maturation after rats have been exposed to 53 mg Al/kg/day, 103 mg Al/kg/day (Steinhagen *et al.,*1979).

Changes resulting in neurodegeneration in the brain, as evidenced by intraneuronal hyper phosphorylated neurofilamentous aggregates are a characteristic response to aluminum in certain species and non-natural exposure situations generally involving direct application to brain tissue, particularly intracerebral and intracisternal administration and in vitro incubation in rabbits, cats, ferrets, and nonhuman primates. Experimental studies involving oral intake of aluminum have not been able to identify any profound any histopathological brain disorders following exposure. defects in the formation of myelin sheath was observed in the spinal cord of mouse whelps when exposed to 330 mg Al/kg/day on gestation day 1 through postnatal day 35. Neurotoxicity over signs are usually not observed at tested doses in the animal studies

(≤330mg Al/kg/day for bioavailable aluminum compounds). Exposure to these doses is associated with insignificant neurological effects detected in tests on neurobehaviour (Stone *et al.*,1979).

Significant alterations in cognitive, sensory and motor function have been observed after exposure to adult or weanling rats and mice or after gestation and/or lactation exposure of rats and mice to aluminum nitrate, aluminum chloride and aluminum lactate. The performance tests usually showing the greatest effects were spontaneous motor activity, forelimb and/or hind limb grip strength, startled responsiveness and sensitivity to heat. In some studies, degeneration in cognitive function have been observed. Other studies, even at higher doses, did not show these changes, Adverse neurological effects were observed in rats and mice at doses of 100–200 mg Al/kg/day and neurodevelopmental effects were also observed in mice and rats at doses of 103– 330 mg Al/kg/day, International Agency for Research on Cancer (IARC, 1981).

The incidence of cancer in workers in aluminum industries has been examined and it was being found that the rate of mortality was higher than expected. Perhaps this is as a result of their exposure to other carcinogens. The possible carcinogens include tobacco smoke and polycyclic aromatic hydrocarbons (PAHs). No biologically significant rise in malignant tumours has been identified in animal cancer studies. The carcinogenic effect of aluminum production was highly recognized and pitch volatilities constantly recommended for epidemiological studies owing to their implication as causative agents (IARC, 1981).

Experimental studies involving chronic, intermediate and acute exposure have also indicated great effects on the respiratory system. The effects include rise in granulomatosis lesions in the lungs, rise in alveolar macrophages, peribronchial lymph nodes as well as increase in lung weight (Drew *et al.*, 1974). The lung problems are a manifestation of dust overload which occurs as a result of failure of the lungs to effectively clear the dust. Lung overload does not depend on the intrinsic toxic nature of the aluminum compound. Moreover, it has been shown that dust overload modifies the poisonous effects as well as the dissymmetry of the compound. When benign dust is excessively accumulated in the lungs for a long time it assumes similar effects as dusts considered as highly toxic. Lack of clarity as to whether the observed respiratory effects are related to aluminum toxicity or to dust overload, inhalation MRLs based on respiratory effects were not derived (Morrow, 1988).

Elusive neurological effects have also been observed in workers chronically exposed to aluminum dust or fumes. These effects include impaired performance on neurobehavioral tests. Neurological tests in the available animal studies have been limited to measurement of brain weight and/or histopathology of the brain; no function tests were performed (Steinhagen *et al.*, 1978; Stone *et al.*, 1979).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1. MATERIALS

All reagents used were food grade and were purchased from Merck (Darmstadt, Germany) samples were analyzed by AA technique using an Atomic Absorption Spectrophotometer from Shimadzu (A.A. 6701F) to determine the amount of dissolved Al.

3.2 METHODS

Five shops were identified randomly within the study area for the purchase of the selected product for the research. The products were bread, canned drink and sachet water. Ten samples of each product were purchased with two from each shop. The purchase was done from most patronized shops by the habitants in the study area. This shop was identified by observation and asking members of the community. The samples for the analysis were sachet water, bread and canned drinks. These were the samples because they are consumed every day and are ready to eat products people consume and the study area was no exception.

SAMPLES OF BREAD

SHOP A	SHOP B	SHOP C	SHOP D	SHOP E
Butter Bread (BA1)	Butter Bread (BB1)	Sugar bread (BC1)	Brown bread (BD1)	Tea bread (BE1)
Sugar Bread (BA2)	Brown Bread (BB2)	Tea Bread (BC2)	Butter Bread (BD2)	Sugar Bread (BE2)

SAMPLES OF THE CANNED COLA DRINK

SHOP A	SHOP B	SHOP C	SHOP D	SHOP E
Canned Cola drink (CA1)	Canned Cola drink (CB1)	Canned Cola drink (CC1)	Canned Cola drink (CD1)	Canned Cola drink (CE1)
Canned Cola drink (CA2)	Canned Cola drink (CB2)	Canned Cola drink (CC2)	Canned Cola drink (CD2)	Canned Cola drink (CE2)

SAMPLE OF SACHET WATER

SHOP A	SHOP B	SHOP C	SHOP D	SHOP E
Sachet water Nes Aqua SA1	Sachet water Nes Aqua SB1	Sachet water Cool Pac water SC1	Sachet water Cool Pac water SD1	Sachet water Living water SE1

Sachet water Happiness water SA2	Sachet water Standard water SB2	Sachet water Special ice water SC2	Sachet water Pure Tina water SD2	Sachet water Pure Tina water SE2

3.3 ALUMINUM CONCENTRATION ANALYSIS

3.3.1 Sample Preparation and Digestion

Digestion for the Sachet water

The samples were acidified with concentrated nitric acid to a lower pH 2. The sample solution was brought to a slow boil till it evaporated to the lowest volume possible of 20 mL. The volume remained was filtered into a 50 ml volumetric flask and was topped up to the mark with distilled water, (UNESCOIHE, 2005).

Digestion Method for Canned drink

The canned drinks were opened and put down for 12 h to allow the gases to escape. Subsequently, 5 ml of 65% HNO_3 acid was added to 45 ml of each portion of the soft drink including a blank in a reaction vessel of Milestone Microwave digester. A time of 10 minutes was allowed for reaction, and the samples arranged in the rotor and placed in the microwave digester and programmed to run at temperature of 170 °C for 15min and held for another 20min to completion. The rotor is cooled to room temperature and the vessels opened with the content transferred into a marked flask for analysis. Analysis is done using GTA 120 Graphite Tube Atomizer.

Digestion for Bread

The bread was mashed and a portion taken, dried in an oven at a temperature of 75°C for 3hrs. The cooled samples were cooled to room temperature, ground and homogenized. About 0.5g of each sampled was then weighed into reaction vessels of a Microwave digester and 8mls of HNO_3 and 2mls of H_2O_2 were added and vessels placed in the rotor.

3.3.2 Atomic Absorption Spectrometry

The sample solution was aspirated into a flame and the sample elements were atomized and vaporized. The flame which contained atoms of the elements were thermally excited by the flame but most remain in the ground state. Absorption of radiation given off by a source (i.e. Hollow cathode lamps) specifically made from that element is done by the atoms in their ground state. This is done at a specific wavelength of radiation which corresponds those absorbed by the atoms in the flame. The absorption follows the Beer's law i.e. absorption is directly proportional to the concentration of atomic vapor in the flame. Both of these variables are difficult to determine, but the path length can be held constant and the concentration of atomic vapor is directly proportional to the concentration of the analyte in the solution being aspirated.

CHAPTER FOUR

4.0 RESULT SAND DISCUSSION

4.1 ALUMINUM LEVELS IN WATER SAMPLES

High levels of aluminum in sources of drinking water is a subject of great concern throughout the world due to the possible effects they can cause. In 1988, Schecher and Driscoll documented that, one of the ways by which aluminum gets into many sources of fresh water is due to the effects of acid rain, acidic water has been documented to have higher levels of aluminum. Srinivisan *et al.,* (1999) also presented a case that, the possible cause of high aluminum contents in sources of drinking water is due to the traditional water treatment process, the use of alum (a coagulant with aluminum base). Aluminum sulphate ($Al_2(SO_4)_3$, mostly known as alum, or polyaluminum chloride (PACl) though are used in water treatment procedures to facilitate the removal of particulate, colloidal and dissolved substances, through a process commonly known as coagulation, can also turn out to be a major way through which aluminum gets into drinking water sources. The various sachet water samples that were collected showed their aluminum contents as represented in the table below.

Table 4.1: Aluminum content of sachet water samples

Sample ID	Aluminum content (µg/L)
SE2	0.031
SB1	0.021
SC1	Below LOD
SE1	Below LOD
SC2	Below LOD
SD1	Below LOD
SD2	Below LOD
SB2	0.026
SA1	0.005
SA2	<0.001

SA -Sachet water from shop A SB-Sachet water from shop B
SC-Sachet water from Shop C SD- Sachet water from shop D
SE- Sachet water from shop E LOD: Limit of determination

The results showed that, samples coded SC1, SE1, SC2, SD1 and SD2 had aluminum content <0.001µg/L. The remaining samples had their content ranging from 0.005 – 0.031 µg/L, with SA1 having 0.005 µg/L and SB2 having the 0.031 µg/L. Considering the two works already mentioned, either or both of the two possible ways of aluminum finding its way into water could be the case for all the samples. Fortunately, the measured levels in the samples were still below the Maximum Contaminant Level (MCL) which was 0.05 to 0.2 mg/L (EPA, USA). It is generally expected that the water company doing the processing and packaging should have methods for the removal of the aluminum. Such methods as documented by Srinivisan *et al.* (1999), in his review may include electrodialysis, cation exchange resin, reverse osmosis, coagulation, sedimentation and filtration (combined). But when treatment methods such as ion exchange (anion), chemical oxidation/ disinfection and aeration/ stripping are used, Srinivisan *et al.* (1999), documented them as ineffective for the removal of aluminum. When the water processing and packaging do not have some of these units potent to remove residual aluminum from the water, the most likely outcome is to have levels beyond the acceptable limits. These samples falling below maximum contamination levels indicate that, there are (most likely), various systems in place to reduce the levels as much as possible in the various water processing companies. Variations among the various samples may have reasons, those with relatively higher values either had more aluminum content to deal with or their system set to control its levels are not as effective as those whose levels were relatively lower. In instances of a day's mishappening, where a particular batch that is produced may have levels beyond that which is acceptable, a constant chemical assessment by the various water company could be a way to identify so as to prevent the progress of the products to the market.

Comparing the results of this work to the analysis by Lopez *et al. (*2002), to investigate the aluminum content of some sources of water, the levels were ranging from 4.2 to 134.1 µg/l; for the various water supply networks, and 15.9 to 165.3 µg/l; for the commercial bottled water samples. They noted differences in the samples that had glass containers (57.6 µg/l) and those that had plastic containers (165.2 µg/l). It could be concluded that, the levels of aluminum contamination in this work is far lower than theirs implying that, the systems of water treatment within the companies from whom samples were taken in this work are more efficient.

4.2 ALUMINUM LEVELS IN CANNED DRINK SAMPLES

The primary exposure of humans to aluminum has principally been attributed to its content in the human diet (Dinelli *et al.*, 2012). They also reported that its physicochemical form greatly influences the uptake distribution and toxicity when consumed by humans. Jagannatha and Murthy (1990) as cited in Dinelle *et al.* (2012), have also reported that, acidic foods, including soft drinks, that may be sold in containers or their caps made of aluminum could have traces of aluminum as its content. The various soft drinks sampled for analysis have their results as shown below.

The results showed aluminum level in the various drinks ranging from 0.62 – 0.175 mg/mL. Lopez *et al.* (2001), also showed the results of aluminum levels in some fruit juices they worked on to range from 49.3 to 1144.6 µg/l. They also showed that, from their sampled soft drinks they analyzed, aluminum contents were between 44.6 and 1053.3 µg/l. The large differences they observed were attributed the varying intrinsic factors of some of the ingredients (like cases where orange and lemon were ingredients of drinks) and the food additives present in the various product. Their results, though comparable to that in this work, show that, soft drinks as analyzed in this work have higher aluminum content.

Table 4.2: Aluminum content of various Canned Cola drinks sampled

SAMPLES	Aluminum content (mg/ml)
CA1	0.072
CA2	0.108
CB1	0.148
CB2	0.135
CC1	0.106
CC2	0.124
CD1	0.175
CD2	0.134
CE1	0.098
CE2	0.062

CA -Canned Cola drink from shop A   CB- Canned Cola drink from shop B

CC- Canned Cola drink from Shop C   CD- Canned Cola drink from shop D
CE- Canned Cola drink from shop E

The cans as were used in the processing and preservation of these drinks are likely to have a contribution to the levels of the element in the drink. This mostly because, certain factors, acid substances, pH, temperature and Cl^- are able to influence the leaching of aluminum into food when they are present in the packages used for the foods (Jagannatha and Murthy, 1990). This may imply that, the conditions the drinks have been subjected to and how long they have stayed on the shelf (the samples used in this work), could also be a great contributing factor to the high levels as observed. Increased in temperature may cause the expansion of the material and this can cause the breaking of some bonds giving way for some metals to be leached into the product. As shown on the ingredient list of these drinks, they have phosphoric acid as content and due to that they have been carbonated, they have carbonic acid dissolved in them. This means that, all these drinks are quite acidic in nature. Again, these soft drinks also have high water content of about 86 – 90% (Mathur, 2003), therefore the use of aluminum contaminated water could also be an influence on the levels of the metal in the drink.

4.3 ALUMINUM LEVELS IN BREAD SAMPLES

In 1997, Lin *et al.,* presented a critical exposure of humans to aluminum contamination is the use of aluminum utensils. When aluminum cans used for cooking are in contact with an acidic, alkaline or salty foods, reports showed that, there may be the dissolving of the element into food (Abercrombie and Fowler 1997; Greger, 1985). Again, it has been reported that, when the cans used for the cooking are new, their contribution of aluminum incorporation into the food are more likely to be higher than when the cans are old (Greger, 1985). Seiyed and Yokel (2005) also reported the possible contribution of Sodium aluminum Phosphate, which is an additive in baking powders, to the aluminum levels in baked products like bread.

All these make it a necessity to assess the levels of the elements in baked products such as bread (the various types as consumed in Ghana). The analysis showed the results as below.

The analysis showed that, the sample with the least content was BB2 (0.603 mg/kg) and that with the highest content was BE1 (5.33 mg/kg). The variations of concentration among the different types of bread is most likely to be related to their varying composition and method of preparation used. This in details may be the different amount of baking powder and its corresponding acidic influence of the dough which may be in the cans for different exposure times.

Table 4.3: Aluminum content of the bread samples

Bread Sample ID	Aluminum content (mg/kg)
BE1	5.33
BA1	1.80
BC2	2.74
BB2	0.603
BA2	0.976
BB1	1.39
BC1	3.33
BD1	2.42
BD2	0.862
BE2	2.42

BA -Bread from shop A BB- Bread from shop B BE- Bread from shop E
BC- Bread from Shop C BD- Bread from shop D

In general, the possible contributing factors to these levels in all the samples may be the factors aforementioned. Stahl *et al.* (2011), in their analysis to investigate aluminum concentrations in bread samples had values between 1 and 14 mg/kg. Though the values are comparable, there seems to be a relatively lower concentration in the samples analyzed in this work. The bakery industry in the country is not highly regulated and many of them do not have standardized procedures to assure quality. Bakers are often persons who may have basically obtained a simple training only in the making of the product without a holistic understanding of the science of that may also be taking place in the series of activities they undertake.

4.4 ALUMINUM LEVELS IN FOODS AND THE CONSUMER

The aluminum levels in consumers may not become problematic on a one-time consumption. It surely will depend on the many factors including quantity in the product, how much of product is consumed, the frequency of consumption, how long the consumption has been and other factors which may or may not be even related to diet as tallied matched with the individual's gender, age, weight, etc. Moreover, Chadwick and Whelan (1993) in their submission presented that, there are several factors within the organism on which the intestinal absorption of aluminum depends; some mentioned were calcium, vitamin D and iron status, the intraluminal pH, etc. Again, there have been reservations in emphatically attributing a causal relationship between the oral ingestion of aluminum and its acute toxicity to human through drinking water and foods. This was due to absence of studies to account established confounding factors and the total intake from all sources (WHO EHC, 1997). This notwithstanding, a provisional tolerable weekly intake (PTWI) was developed by JECFA in 2007 from all sources to be 1 mg/kg of body weight (FAO/WHO, 2007).

Consumers who may not be in the position to have knowledge about the effects of consuming products with high levels of aluminum may be at a high risk (future research works may put the understanding aright). Due to the awareness created on how beneficial it is to take much water, many consumers have made personal commitments to drinking a lot of water in the

desire to reap its potential benefit and many have soft drinks and breads as one of the main constituents of their diets. Should all these tend to have high values of aluminum content increasing the daily consumption rate of the consumers, there could be various health implications. This becomes very important because a simple sensory assessment (visual, taste, smell, etc.) of any food product cannot give a good judgment of its chemical content, and they may not be in the position to be daily assessing every food product, much of the duty will have to be taken by the regulatory bodies. Creating an awareness of potential dangers of traces of aluminum in food to sensitize consumers may be needful because it will make them always demand the best from the processing companies and the various
regulatory bodies.

Though the knowledge of persons in the various industries has not been assessed with regards to potential dangers of aluminum contamination, there may still be a necessity to raise their awareness (if they do not know) of what it could be. This may incite a positive attitude to constantly assure that quality measures set to eliminate or significantly reduce the levels in the product are well adhered to. As the deliberation continues on the possible positive correlation between aluminum ingestion and disease causation, even now various regulatory bodies, including the Food and Drugs Authority, Ghana Standards Authority, Environmental Protection Agencies, etc., may need to become more particular with their inspection and certification process so as to maintain a community where foods will not have aluminum level exceeding the current tolerable limits. Their particularity in this regard may be very needful because some companies may be very careful to adhere to all safety standards when they want certification but on attaining the certification, their safety standards are less critically controlled especially when there is very little inspection by the various regulatory bodies.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The study showed that six of the water samples had aluminum levels <0.001µg/L and the remaining samples to be ranging from 0.005 – 0.031 µg/L, the canned drinks had aluminum levels within 0.62 – 0.175 mg/mL and the bread samples had aluminum content between 0.603-5.33 mg/kg. The values were comparable to the results of other research works and then they fell within acceptable ranges. This gives the indication that, though the aluminum find its way into the various food by different ways, the final product still remains safe for consumption. The challenge may present itself when there is accumulation beyond tolerable limits due to frequency and quantity of consumed sources of contamination. That notwithstanding, the effect of the contamination will also be dependent on the consumer.

5.2 RECOMMENDTION

Research should be conducted to investigate the levels in the many products that may have traces of aluminum due to their composition or processing method. Exposure assessment of various consumers of these foods should also be investigated since that will better show how the consumer is at risk, this could be a basis to initiate an epidemiological study. Awareness should be created among food processors and even consumers on the possible ways aluminum could get into foods and the potential harm they may pose to people who consume them.

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