

**SCHOOL OF PUBLIC HEALTH
COLLEGE OF HEALTH SCIENCES
UNIVERSITY OF GHANA**



**ASSESSMENT OF URINE FLUORIDE CONCENTRATION AMONG
POTROOM WORKERS OF VOLTA ALUMINIUM COMPANY
(VALCO), TEMA**

BY

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**THIS DISSERTATION IS SUBMITTED TO THE UNIVERSITY OF
GHANA, LEGON, IN PARTIAL FULFILLMENT OF THE
REQUIREMENT FOR THE AWARD OF MASTER OF PUBLIC
HEALTH (MPH) DEGREE**

JULY, 2019

DEDICATION

This work is dedicated to the memory of my late mother, Gladys Naana Animwaa Yeboah. It is also dedicated to the Management and staff of Volta Aluminium Company, VALCO whose support made this work possible.

ACKNOWLEDGEMENT

Foremost, I give glory to the Almighty God for His protection and guidance throughout the entire program. None of what I have achieved today would have been possible without Him.

I acknowledge the support of my supervisor, Dr. Mawuli Dzodzomenyo at the Department of Biological, Environmental and Occupational Health under whose directions this was made possible. When the going got tough, I had to rely on his encouraging words to find the strength to continue.

I am deeply indebted to Mr. James Provencal, Bishop Dr. Kwabena Amonoo-Neizer, Madam Elizabeth Davies and especially Mr. Edward Arthur all of VALCO for their immense support and contributions during the conception, data collection and the write up of this project. Special thanks to Mary, the assistant who helped with the data extraction.

To my family, Portia, Brian and Naana, I say thank you for the understanding and the sacrifices you had to make for my periods of absence. Thank you, Portia for reading through and your valuable suggestions and corrections.

Lastly, kudos to all my course mates especially to you Kingsley, Otoo, Emefa, Priscilla, Yvonne, Miriam and all you good people. We made it. God bless us all in all our endeavors.

ABSTRACT

Introduction: Due to rapid industrialization, health problems among industrial workers due to fluoride poisoning are on the rise. Emissions of fluoride dust and fumes from the smelters of primary aluminium producing industries are dissipated in the work environment and poses occupational health hazard. The Use of cryolite (tri-sodium hexafluoroaluminate, Na_3AlF_6) as a flux in the conversion of alumina to aluminium is the major source for fluoride emission responsible for the spread of industrial fluorosis among smelter workers.

Objective: The objective of this study was to determine the urine fluoride concentrations among potroom workers of VALCO and to determine if there was a significant difference between the pre and post shift urine concentrations.

Methods: An industrial based cross-sectional retrospective study design and quantitative research approach was carried out using extracted data on all employees working in the potroom from the human resource department's database. Pre and post shift urine were sampled from eighty two (82) potroom workers selected conveniently after obtaining their consent to participate in the study. The samples were analyzed using the ion selective electrode (Model: Mettler 4, USA INC). A non-participant observation was conducted in the potroom to observe availability and adherence to the use of personal protective equipment (PPEs). Stata software version 15 was used to analyze the data collected. Bivariate analysis using Chi square test of independence was performed to test the associations between dependent and independent variables. Multiple logistic

regression was carried out on the factors that were significant at the bivariate level, crude and adjusted odds ratio were computed and statistical significance was set at $p < 0.05$.

Results: The results showed that the overall estimated proportion of potroom workers with high levels of fluoride in preshift urine was 9.8% [0.98 ± 0.32 (95% CI = 0.03-0.16)]. All 82 participants however had their post shift urine fluorides within recommended limit of 7ppm [1.48 ± 0.17 (95% CI = 1.15-1.837)]. There was a statistically significant difference in preshift and post shift urine fluorides among the potroom workers ($p < 0.001$). The job category was found to be significantly associated with preshift urine fluoride levels (AOR=1.21; 95% CI=1.01-4.32, $p < 0.042$).

Conclusion: Potroom workers of VALCO were exposed to acceptable levels of potroom fluoride.

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LIST OF ABBREVIATIONS

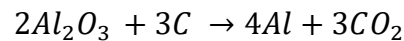
ACGIH	American Conference of Government Industrial Hygienist
HF	Hydrogen Fluoride
BEI	Biological Exposure Index
ISE	Ion Selective Electrode
NIOSH	National Institute of Occupational Safety and Health
NaF	Sodium Fluoride
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PPM	Parts Per Million
PPE	Personal Protective Equipment
TISAB II	Total Ionic Strength Adjustable Buffer
TLV	Threshold Limit Values
TWA	8-Hour Time Weighted Average
VALCO	Volta Aluminium Company

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Aluminium is produced from alumina through the Hall-Hèroult electrolytic process. This process is more than a century old. It involves the electrolytic reduction of alumina (Al_2O_3) in the presence of carbon into aluminium and carbon dioxide. Chemically, the reaction can be represented as;



This process takes place in carbon coated steel containers known as pots. The pots also serve as the cathodes for the electrolytic reaction while anodes are made of baked carbons. The pots are lined together (usually in batches of hundred) and are housed in a common area known as the potroom (Sim & Benke, 2003). The pots contain cryolite salt bath into which the alumina is dissolved at high temperatures ($960^\circ C$). The dissolved alumina is electrolyzed into aluminium and oxygen.

The aluminium formed, sinks to the bottom of the pot because of its density. The oxygen released as a result reacts with the carbon baked anodes consuming them up and releasing them as carbon dioxide. In the process, residual hydrogen ions are oxidized into water that reacts with the cryolite salts to form fluoride compounds (Dando, Xu, & Peace, 2008).

These fluoridated compounds escape as fumes and dust polluting the immediate potroom atmosphere. These compounds are linked to the development of some occupational health conditions such as occupational asthma and fluorosis. Fluorosis is a chronic condition caused by excessive intake of fluorine compounds, marked by mottling of the teeth and, if severe, calcification of the ligaments (WHO, 1996). Dental fluorosis is a common disorder, characterized by hypomineralization of tooth enamel caused by ingestion of excessive fluoride during enamel formation (Dando, Xu, & Peace, 2008). Potroom workers who get exposed to these fluoridated compounds may develop some of these occupational health conditions.

To reduce workers exposure and prevent the development of occupational health conditions, modern systems have evolved. One such important development is the prebake technology which has favorable environmental pollution profile (Hodge et al., 2012). This reduces the atmospheric contamination in the prebake work atmosphere. However, the aluminium industry remains second highest in fluoride emissions (Susheela, Mondal, Tripathi, & Gupta, 2014).

Exposure to fluorides over a long period of time may lead to the development of fluorosis and other respiratory symptoms when inhaled. In the aluminium industry where fluoride containing ores are handled by workers, prolonged exposure is an important risk factor. According to Hodge (1977), urinary excretion of 5 ppm of fluoride is a danger sign for the development of fluorosis. Fluoride content of 2.5 mg/m³ in the potroom atmosphere is also a danger sign for the development of fluoride associated respiratory symptoms.

Fluorosis is preventable but not curable (Susheela et al., 2014). It mainly affects the bones, joints, ligaments, teeth and other soft tissues in mammals (Davison & Weinstein,

2006). Accumulation of fluoride in the muscles, bones and joints induces pains. It also leads to discoloration of teeth and bone deformation. Fluoride accumulation leads to complaints of joint pains and back stiffness. Fluorosis may also lead to developmental neurotoxicity leading to cognitive impairment (Grandjean & Landrigan, 2006). Short term exposure may also lead to manifestations such as non-ulcer dyspepsia, abdominal discomfort, joint pains and muscle weakness. These symptoms can be prevented through early recognition and regular monitoring (Susheela et al., 2014) of fluoride levels.

Urinary excretion of fluoride is a reliable indicator of the extent of exposure. Regular monitoring of urinary fluoride through the use of ion selective electrodes ensure early recognition and removal or containment of sources of exposure (Boers et al., 2017).

1.2 Problem statement

The Aluminium industry is the second highest fluoride emission industry. Acute exposure to fluoride is associated with the development of eye irritation, laryngeal oedema, wheezing, nausea, vomiting, diarrhea, tremors and convulsions. Long term exposure to fluoride leads to the development of fluorosis, an incurable medical condition (Susheela et al., 2014). Several studies have also linked occupational exposure to fluoride with the development of occupational asthma and other respiratory symptoms (Boers et al., 2017). Though the exact mechanism is not yet known, some studies have established that increasing exposure to gaseous and inhalable fluoride particles increases the incidence of respiratory and musculoskeletal symptoms.

Volta Aluminium Company, VALCO, is a primary aluminium smelter that produces aluminium for the local Ghanaian industries and the international market. VALCO has an

installed capacity of 200,000 metric tons of primary aluminium per year. The researcher with over three years' experience as a medical officer in charge of VALCO hospital has observed that potroom workers of VALCO are at increased risk of fluoride exposure. Anecdotal evidence from the VALCO hospital suggest high incidence of respiratory and musculoskeletal complaints among workers attending the hospital. While these symptoms may be fluoride related, there are no studies conducted in the plant to determine the extent of fluoride exposure among workers in the plant. Exposure to fluoride may result in the development of acute and chronic symptoms which may result in loss of production time, increased health expenditures and increased cost of production.

This study aimed at identifying the extent of workers exposure to fluoride and to improve formulation, implementation and evaluation of sustainable institutional-based health and safety policies to prevent the development of fluoride associated occupational health conditions.

1.3 Conceptual framework

Figure 2 below summarizes the conceptual framework of the relationship between independent variables and urine fluoride levels of potroom workers. Workplace fluoride exposure is influenced by the type and proximity of the job to the emitting source. Regular pot nursing activities such as aluminium tapping, changing of carbon anodes or bath removal brings the potroom worker close to the fluoride emitting source (Dando et al., 2008). The availability of personal protective gears including respirators and face masks also significantly affect the amount of fluoride the worker is exposed to. Exposure

to fluorides is also a function of time. The longer the duration of exposure, even to lesser amounts, the more the levels in biological tissues.

Again, one's age and duration of service may influence one's level of knowledge of occupational hazards and safety practices. In addition, the availability of safety protocols and standards within the work environment, the use of personal protective equipment and enforcement of safety precautionary rules are also direct determinants of workers knowledge of occupational hazards and practice of safety which would in turn influence their exposure.

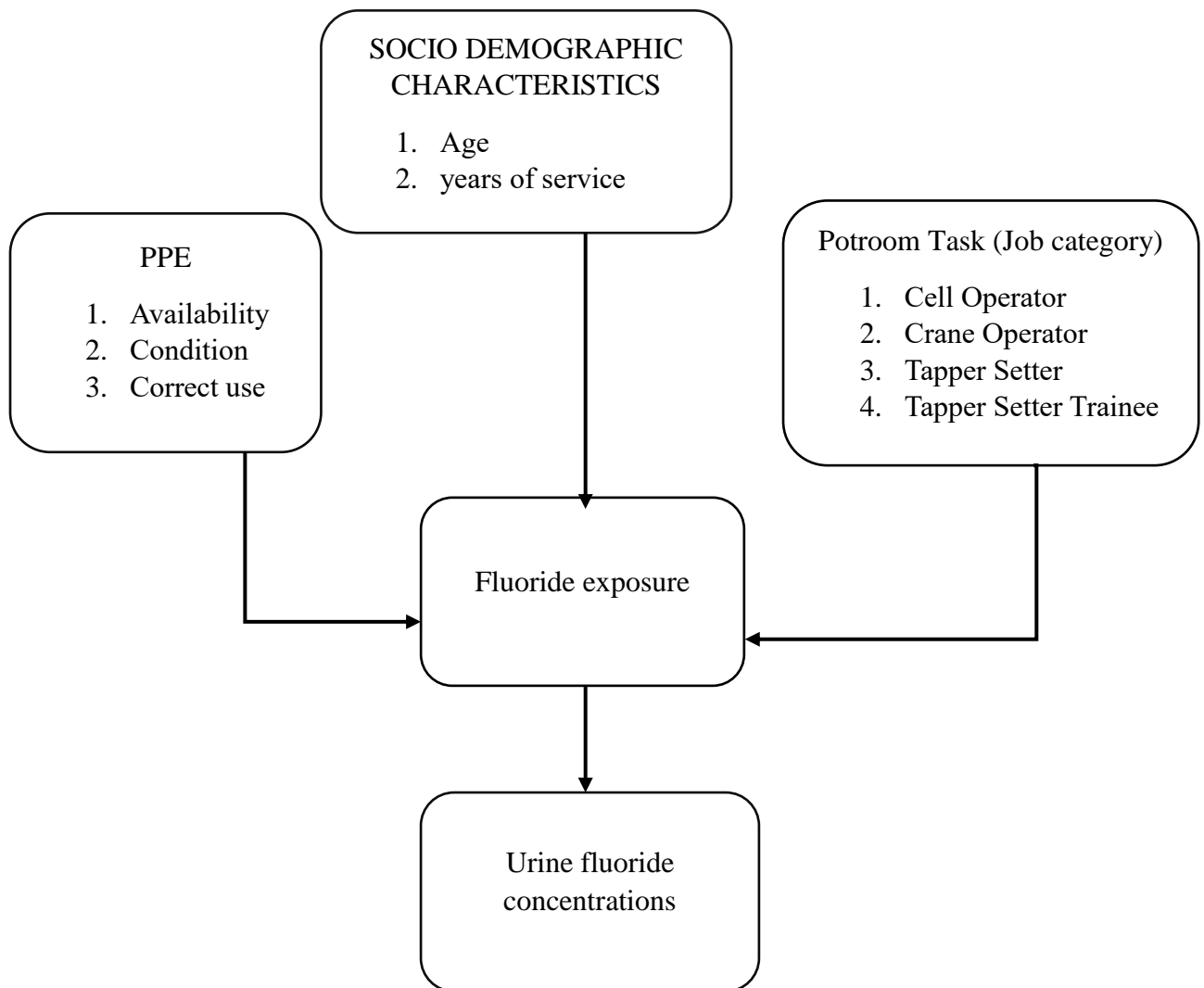


Figure 1: Conceptual Framework on potroom fluoride exposure and factors determining exposure

1.4 Justification

The primary aluminium industry is estimated to be the second highest source of fluoride exposure. Exposure to pollutants in the aluminium industry is linked to the development of occupational asthma, musculoskeletal pains and cancer. These conditions together contribute substantially to lost time at the workplace.

According to the International Labour Organization (2014), an estimated 2.3 million deaths occurred globally as a result of occupational related conditions. This has resulted in several interventions globally including the adoption of the prebake technology which has a relatively superior emissions profile compared to the Søldeberg technology (Benke, Abramson, & Sim, 1998; Sim & Benke, 2003). Newer aluminium smelting plants have also automated most of their processes including the use of overhead cranes to reduce exposure to fluoride. Local exhaust ventilation systems are also used for extraction of potroom fumes to reduce atmospheric exposure. Despite these technological improvements, workers still face some exposures at the workplace.

The VALCO plant is a relatively new smelting plant. Construction began in 1964 and smelting operations began in 1967. It uses the prebake technology of smelting and uses automated processes in the potroom.

Although VALCO has been monitoring urine fluoride concentrations of potroom workers quarterly, there has been no study to determine the level and the determinants of exposure among the potroom workers. This study would help to bridge this gap.

1.5 Research questions

1. What is the proportion of potroom workers with high concentration of fluoride in their urine at VALCO?
2. Are there differences in pre and post shift urine fluoride concentrations among potroom workers at VALCO?
3. What factors influence urine fluoride concentrations among potroom workers of VALCO

4. Are PPEs available for potroom workers and are they being used correctly?

1.6 Objectives

1.6.1 General objectives

The objective of this study was to investigate urinary fluoride concentration among potroom workers of Volta Aluminium Company, VALCO.

1.6.2 Specific objectives

1. To determine the proportion of potroom workers with high fluoride levels in their urine.
2. To determine the pre and post shift urine fluoride concentration among potroom workers.
3. To assess factors that influence urine fluoride concentrations among potroom workers of VALCO
4. To assess and describe the use of PPEs among potroom workers of VALCO.

1.7 Hypothesis of Study

H₀: There is no significant difference between pre and post shift urine fluoride concentrations.

H₀: There is no significant exposure to fluoride among potroom workers at VALCO.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

Fluoride is from fluorine and it is naturally found in the form of compounds with other elements. Humans are daily exposed through air inhalation, food and water. The rocks and minerals in an area determine to a large extent the amount of natural fluoride contamination in the area. Some fluoride bearing rocks include cryolite (Na_3AlF_6), apatite ($\text{Ca}_5[\text{PO}_4]_3\text{F}$), pegmites such as tourmaline, fluorspar (CaF_2) and topaz ($\text{Al}_2\text{SiO}_4[\text{F},\text{OH}]_2$) (Buxton and Shernoff 1999; WHO, 1994). Because of its high reactivity, fluoride can replace the hydroxyl group of some minerals such as muscovite (Hurtado et al., 2000).

Exposure to high concentrations of fluoride over a long period of time may lead to fluorosis. Fluorosis is a chronic condition caused by excessive intake of fluorine compounds, marked by mottling of the teeth and, if severe, calcification of the ligaments (WHO, 1996). Fluorosis mainly involves the skeletal and dental tissues. Other organs that can be affected include the kidneys, endothelium, gonads and the brain cells. Fluorosis is found in all continents and it is of public health concern (NRC, 2006; WHO, 1996).

Fluoride is cariostatic hence reduces the chances of dental caries. It is thus recommended for regions with low fluoride contents to encourage fluoridation of their public water systems to reduce the burden of caries in those communities however the part played by fluoride in achieving full human potential remains uncertain. However, some studies

have discounted this potential benefit of fluoride in reducing dental caries in some populations (Nielsen, 2009).

According to the agency for toxic substances and disease registry (ATSDR) the daily intake of fluoride for minimal risk is 0.05mg/kg/day while the non-observable adverse effect level (NOAEL) is 0.15mg/kg/day. Lethal doses depend on the age of the exposed person. Lethal doses range from 3 to 16mg/kg in children and 16-64mg/kg in adults (ATSDR, 2003).

Progressively organofluoride compounds are being used in industries. A fifth of medications and over a quarter of agrochemicals are fluoride compounds. Because of the strength of the carbon-fluoride bond, many of these compounds persist and cause environmental and health related issues (Weinstein and Davidson, 2004).

2.1 Sources of Fluoride Exposure

2.1.1 Air

Fluorine, from which fluoride is derived, is the seventeenth element and represents about 0.06-0.09% of the earth's crust. It is found in the air, water, plants and animals in our cities and villages. One can be exposed through breathing, drinking and eating. Air contamination with fluoride is as a result of multiple and varied sources of fluoride release into the environment (Hodge et al., 2012). It is also found in soil, rocks and minerals some of which are of commercial importance. Cryolite used in the aluminium smelter industry contains about 4.2% of fluoride and it is the main source of exposure in the primary aluminium industry. Dust from heated fluoride containing soil and industrial waste may be blown over long distances widely distributing fluoride in the atmosphere.

According to a study in some provinces in china, the use of fluoride rich coal for domestic heating and chores resulted in high indoor air concentration of fluoride (Fawel et al., 2006). Effluvia from volcanic eruptions are also important sources of fluoride contamination in the air. According to Hodge et al. (2012), one significant challenge in estimating the amount of fluoride in the atmosphere is the difficulty in differentiating gaseous from particulate fluoride contaminants in the air. Fluorides existing as hydrogen fluoride and silicon fluoride are more commonly detected in measuring fluoride content in the air. However for fluoride in the air to exert any biological effect, it must exist in the ionic form to make that possible (Hodge et al., 2012).

In nature, fluorides occur in many naturally occurring materials like coal, clay, and minerals. These substances, when heated to high temperatures in aluminium smelters; glass, brick, tile works and plastic factories, the possibility of fluoride release to the atmosphere are high (WHO, 1994).

2.1.2 Water

Fluoride is present in various water bodies at varying concentrations. For instance, seawater contains between 0.8-1.4mg/L of fluoride. The average fluoride content of water obtained from lakes, rivers or artesian wells is below 0.5mg/L. The permissible limit of fluoride in drinking water according to the world Health Organization is 1.5 ppm (mg/l) (WHO, 2010). Few of these water bodies however have very high concentrations. A concentration of 95mg/L however has been reported in Tanzania. Lake Nakura in Kenya is reported to have the highest recorded natural fluoride with a concentration of 2800mg/L.

Anthropogenic activities such as the use of pesticides, fertilizers, sewage and sludges in agricultural activities can also increase the fluoride level in water sources (Tiwari et al., 2011). Fluoride at low concentration in drinking water has beneficial effects on the teeth including the prevention of dental caries in children, whereas other people exposed to high concentrations of fluoride are reported to suffer from various adverse effects.

Conversely, improving the quality of water supplied and defluoridation are among the major steps necessary to combat fluorosis in fluoride-endemic areas. Water from bottled sources also has varied concentrations of fluoride. This is mainly dependent on the source of the water. Though bottled water consumption is on the increase in Ghana, most of these do not have their fluoride and other mineral concentrations stated on their labels. This is important and regulatory steps must be taken to protect vulnerable populations such as children since consumption of high levels of fluoride above recommended guidelines have public health significance (WHO, 2010). Studies conducted in recent years suggest that fluoride is a neurotoxic agent, as research conducted in populations exposed to fluoride with water concentrations higher than 3 mg/L supports the hypothesis that fluoride ions decreases the intelligence quotient (IQ) of children (Lu et al., 2000).

A study was conducted in San Luis Potosi, India to determine the risk factors associated with human fluoride exposure through drinking water. The preparation of food with tap water was observed to be one of the major source of fluoride exposure. This was so because about 83.8% of the study population used tap water for drinking, and 100% used it for cooking (Grimaldo et al., 2016). No difference was found between hard and soft drinking water, or between natural and artificially fluoridated drinking water, and the bioavailability of fluoride.

It is estimated that nearly about 355 million people worldwide are receiving fluoridated water artificially. Another 50 million people obtain naturally fluoridated water with 1 mg/L concentration (WHO, 2010). In some developing countries, including some parts of India, Africa and China, drinking water can hold more than the WHO's recommended Guideline Value of 1.5 mg/L concentration. Community water fluoridation and fluoride toothpastes are considered the most common source of fluoride exposure (US Public health, 2015).

2.1.3 Food and Beverage

Unrefined food has low fluoride content between 0.1-2.5mg/kg. The average content of fluoride in commercially available tea is 1.5mg/L (Malinowski et al; 2008). Certain cooking practices are also known to introduce fluoride into the food chain. The use of meat tenderizers in some parts of Africa is associated with high fluoride content in food. The use of fluoride rich coal for cooking in some China provinces also increases human exposure to fluorides. Foods can acquire fluoride from the use of fluoridated water during preparation. This is very important in preparing infant formulas for children. Tegegne et al., (2014) reported that processing parboiled rice and cooking rice with high fluoride-containing water can increase the level of fluoride significantly.

Arora and Bhateja (2015) estimated mean fluoride concentration in wheat, rice and potato in Mathura city and found significant concentrations of fluoride in rice and wheat. They concluded that crops, namely wheat, rice and potato can be an additional dietary source of fluoride. The uptake of fluoride is reduced when ingested with calcium-rich liquids or foods.

2.2 Fluoride pollution

Poor environmental emissions standards can result in elevated atmospheric fluoride levels (in excess of $1.4\text{mg}/\text{m}^3$). According to Hodge et al., (2012), the National Academy of Sciences in the United States estimates these industries to be among the major industrial sources of fluoride emission in the United States. These industries include aluminium smelters, superphosphate fertilizer plants, glass manufacturing, coal burning industries, brick and tile manufacturing plants and steel manufacturing industries. These industries are known for high fluoride emissions with resultant damage to environmental and human health (Hodge et al., 2012).

Ninety percent of air sampled in an industrial city in the Federal Republic of Germany in a decade long study, beginning in 1955 found fluoride levels in the ranges of $0.5\text{-}3.8\mu\text{g}/\text{m}^3$ while that from their non-industrialized counterparts was between $0.05\text{-}1.90\mu\text{g}/\text{m}^3$. These call for stronger emissions control standards especially in developing countries like Ghana seeking to industrialize (Morton et al., 2011).

2.3 Fluoride metabolism and Absorption

Fluorides move across most membranes as hydrogen fluoride (HF) along a pH gradient. HF is weakly acidic. Half of its concentration will dissociate into hydrogen and fluoride ions at a pH (pKa) of 3.4 while the other half will remain undissociated. HF moves across membranes in a nonionic diffusion fashion from an acidic solution to an alkaline or basic solution. It has a permeability coefficient that approaches that of water (Grimaldo et al., 2016).

Fluoride absorption takes place in the gastrointestinal tract. The first significant point of absorption is the stomach. About 20-25% of ingested fluoride is absorbed in the stomach. Absorption in the stomach is dependent on the acidity of the stomach, the gastric content and the gastric emptying time (Nopakim et al., 1989; Pashley, 1984; Whitford, 1996). A higher acidic environment favors a higher fluoride absorption hence a higher peak plasma concentration (Whitford, 1996). When gastric emptying is delayed, fluoride absorption is also delayed (Nopakim et al., 1989). Fluoride forms insoluble complexes with bi and trivalent cations such as calcium and aluminium (Trautner and Siebert, 1986). These complexes reduce the amount of fluoride absorbed. These insoluble fluoride complexes are excreted through faeces. These cations thus reduce the bioavailability of fluoride.

2.4 Fluoride distribution

After ingestion, fluoride peaks in plasma within an hour and return to baseline plasma levels in 11 hours (Whitford, 1996). This is as result of renal excretion and deposition into hard and soft tissues. Fluoride exist in plasma as inorganic ionic fluoride and protein bound fluorocarbons. The inorganic forms are bioactive and are largely responsible for the biological, medical and public health significance of fluorides in living tissues. Plasma fluoride levels are dependent on the amount ingested. Persons in fluoridated areas have plasma fluoride averaging between 0.5-1.5 μ mol/L (Whitford, 1996).

Fluoride distribution in the visceral organs is influenced by the blood flow rate to the organ and the pH gradient existing between the extracellular and the intracellular spaces. Since fluoride accumulates more in alkaline medium, the extracellular fluid accumulates

more fluoride (Whitford, 1979). Concentration of fluoride decreases across the organs as follows: kidney, liver, lung, spleen and others (Whitford et al., 1979).

About 99% of the total fluoride content in the body is held in calcified tissues which are mainly bones and teeth. About 55% of absorbed fluoride is deposited in calcified tissues in children aged seven or less while such tissues in adults between ages 18-75yrs take about 36% of absorbed fluoride (Villa et al., 2010). Different regions in bones contains varied fluoride amount (Richard et al., 1994). Bones and dentine hold similar fluoride content. Enamel however has a different fluoride content which is unrelated to that of bone or the dentine. Enamel content is mainly a function of fluoride exposure at the time of tooth formation.

2.5 Fluoride excretion

Renal excretion of fluoride is 60% and 45% in adults and children respectively (Villa et al., 2010). Fluoride is removed from the blood at the glomerulus and reabsorbed at the proximal convoluted loop depending on the acidity of the forming urine (Whitford, 1994). In acidic urine, fluoride exists as HF which readily diffuses across the cell membranes thereby accumulating fluoride in plasma. Alkalinizing urine therefore enhances fluoride excretion (Erstrand, 1996). Fluoride may also be excreted through faeces when it forms insoluble complexes with some polyvalent cations (Whitford 1996).

Once fluoride is absorbed, it is cleared from the plasma through excretion in urine, and to some extent in saliva and sweat, and by the uptake in calcified tissues. About 50% of the absorbed amount is excreted via urine during the following 24 hours, most of the remaining amount is incorporated into calcified tissues. Since fluoride is a keen hard

tissue seeker, about 99% of the body burden of fluoride is found in calcified tissues such as bone (where fluoride ions replace hydroxyl ions in hydroxyapatite crystals), and teeth (during pre-eruptive tooth development). Besides bone and teeth, fluoride is also found in the pineal gland, another calcifying organ (Grimaldo et al., 2016).

2.6 Modulation of fluoride metabolism

Modulation of fluoride metabolism is largely achieved by interference in absorption and excretion. This can result from metabolic, genetic and systemic alterations in the body that leads to imbalances in hormones, sleep pattern, physical exertion and acid-base abnormalities.

2.6.1 Acid-base abnormalities

Factors that influence acid-base variations have an effect on the tissue concentration of fluoride. Dietary composition such as vegetarian diet affects the pH of tissue which in turn affects the fluoride concentration in tissues. Vegetarian diet, which is basic, causes increase loss of fluoride in urine (Whitford, 1996).

2.6.2 Physical activity and hormones

Physical exertion increases the acidity across membranes. This pH gradient causes HF to diffuse from extracellular fluid to intracellular compartments especially in skeletal muscles (Whitford, 1996). Parathyroid hormone levels and urinary fluoride excretion directly correlates with plasma fluoride concentrations (Cardoso et al., 2008).

2.6.3 Diet composition

Plasma and urinary acidity can be influenced by dietary composition. Fluorosis can be controlled with diets. The vegetarian and calcium rich diets reduce fluoride uptake by rendering urine acidic and forming insoluble complexes with fluoride respectively. Chen et al. (1997) demonstrated dental fluorosis rate of 7.2% and 37.5% in milk and non-milk drinking groups.

Sometimes, fluoride accumulates in the roots, grains, shoots or leaves and the level of accumulation depends upon the fluoride concentration in air, and water (Gautam and Bhardwaj, 2010).

The second largest source of exposure is food. The fluoride level in fresh food is not only dependent on where it was processed, but also on the water it was prepared with. In Europe the fluoride content in food is generally low, between 0.02 to 0.29 mg/kg, but food stuff such as fluoridated table salt, fish, tea and bottled natural mineral water may contain higher fluoride concentrations (National Institute for Dental and Craniofacial Research, 2014).

In countries such as Ireland, the UK, Australia and New Zealand, where there is habitual tea drinking, the major dietary source of fluoride ion is tea consumption (Jacqmin-Gadda et al., 2010). In addition to tea, fluoridated water and toothpaste are also major sources of fluoride exposure. Other beverages produced from fluoridated water such as powdered infant formula, fruit juices, soft drinks and coffee also contribute to fluoride exposure. Other food sources of fluoride exposure include pesticide residues in foods, foods processed or cooked in fluoridated water; foods grown in soil containing fluoride ions or irrigated with fluoridated water (Cardoso et al., 2008).

2.7 Fluoride effect

The beneficial or harmful effect of fluoride depends on the plasma concentration. Minimal doses offer beneficial effects such as caries prevention while larger doses manifest as fluorosis (Burt and Eklund, 1999).

2.7.1 Dental and skeletal fluorosis

Intake of fluoride helps prevent tooth decay known as dental caries. The post-eruptive protective effect is attributed to the reduced acid production by plaque bacteria and an increased rate of enamel remineralization. As such, the dental community generally favors the ingestion of fluoride to promote good dental health (Miller-Ihli et al., 2003). Orally ingested fluoride is readily absorbed from the gastrointestinal tract. Nearly all of the fluoride in the body is found in calcified tissues and any elimination is done through the kidneys. Fluoride in drinking water may help to prevent tooth decay, if the level of fluoride ranges between 0.7 and 1.5 ppm, as recommended by the World Health Organization (Roberto and Jorge, 2004). A study carried out on children supplied with water containing less than 0.3 ppm fluoride had a higher incidence of dental caries compared with another group of children supplied with fluoridated water at 1.5ppm (Antwi, 2006).

The ingestion of fluoride over 1.5 ppm over long periods of time produces severe effects on human health, such as dental and skeletal fluorosis, osteoporosis, hip fracture, arthritis, mental retardation and premature aging (Roberto and Jorge, 2004). Children between the ages of 2–3 are at most risk of suffering from cosmetic fluorosis but some evidence suggests that enamel fluorosis in primary teeth may be the result of infants ingesting formula reconstituted with fluoridated water. Skeletal fluorosis is the result of

ingesting elevated levels of fluoride for extended periods of time (Miller-Ihli et al., 2003). Experts in skeletal fluorosis agree that ingestion of 20mg of fluoride a day for twenty years or more can cause crippling skeletal fluorosis (Chen et al., 1997).

2.8 Urine as an estimator of fluoride exposure

According to the WHO (2014), biological samples suitable for assessment of fluoride exposure include plasma, saliva and urine. Urine fluoride excretion is a function of total fluoride exposure. Urine fluoride concentration is a good predictor of group exposure as opposed to individual exposure. Post shift urine fluoride concentration is a good estimator of acute fluoride exposure at the workplace. Since fluoride excretion is not constant throughout the day, a 24-hour urine sample collection is more reliable than random or spot sample for the estimation of average fluoride exposure. It is also observed that fluoride levels in morning urine samples can be a good estimator of fluoride exposure (Ndejjo et al., 2015).

2.9 Occupational hazards and Use of personal protective equipment (PPEs).

Occupational health is concerned with health and its relation to work and the working environment. It applies not only to health promotion but also health protection, emergency healthcare and a wide range of preventive, curative and rehabilitative services. It is a concept which includes everything that can be applied to promote health and working capacity of workers (Awodele et al., 2014). Workers involved in all manner of industries including machinery, air transportation, medical and other health services, textile and metal manufacturing, or petroleum and coal production are more likely to

have a higher risk of being exposed to high levels of cryolite in the air if not adequately protected with appropriate personal protective equipment (PPEs) (Choubisa et al., 2010). In a study conducted by Ashish et al., (2011) among Aluminium smelter workers in Bangladesh, only 25% of the workers were observed to be using one or other form of PPEs during the course of work in the potroom. The PPEs used by these workers were mainly hand gloves, boots, masks, helmets, eye glasses and ear plugs. However in another study in India, 51% of the workers in an aluminium smelter were found to use PPEs. The most common reason given by the workers for not using PPEs was that it was not necessary or needed.

Safe work and workplace environment through improved occupational health and safety practices enhances productivity among workers (Upadhyaya, 2014). However, industrial occupations may create unsafe work and work environment because of the inherent hazards present in their materials, processes, technologies, or the products. These hazards may pose the risk for accidents and work related diseases to the people within the industrial premises in particular and the general public in proximity to the workplace as well the environment in (Tiwari et al., 2011).

Tiwari et al., (2011) found out that educational status, work experience, safety training, and availability of work regulation were found to be associated with the use of PPEs. They also reported that workers who had attained at least a certificate in their education are more likely to use personal protective equipment than those who just attended primary school and graduated without a certificate. Awodele et al., (2014) also observed that potroom workers who had safety training were 98% more likely to use personal protective equipment as compared to workers without safety training.

Availability and use of PPEs such as hand gloves, nose mask, overalls, safety boots and protective goggles in industrial settings have been found to reduce exposure to occupational hazards (Awodele et al., 2014).

Awodele et al., (2014) conducted a study on fluoride exposure among potroom workers in aluminium industry in Nigeria, samples of urine and serum were taken for the analysis. The fluoride content in serum varied from 0.06 - 0.17 mg/L in case of pot-room workers and 0.01-0.04 mg/L in case of non potroom workers. Tiwari et al., (2011) also found fluoride content in urine to vary from 0.53 - 9.50 mg/L and 0.01-0.04 mg/L in the case of potroom workers and non potroom workers respectively in a comparative study conducted among workers in an aluminium industry in Iran.

In most studies, the researcher observed that, though the average fluoride in urine of pot room workers were high above recommended limits, no visible sign of fluorosis was found. In a study conducted among 53 workers occupationally exposed to fluoride in an aluminium smelting factory in Sweden, mean plasma fluoride levels in workers at the end of their shift was reported to be 2.54 μM (Ehrnebo and Ekstrand, 2014).

Kono (2011) also reported serum urine fluoride levels ranging from 2.21 to 3.47 μM among exposed workers in aluminium smelter industry in Japan. High prevalence of occupational injuries and exposure among workers may suggest that either the PPEs are not being used or are not effective. There is also the need for constant training of all categories of workers on measures that must be taken in order to prevent occupational hazard exposure (Tiwari et al., 2011).

CHAPTER THREE

3.0 METHODS

3.1 Study site

The study was conducted at the premises of VALCO in the Tema Industrial Area enclave. Tema is the hub of industries in Ghana. Volta Aluminium Company also known as VALCO is a primary aluminium smelter. It is the second largest aluminium smelter in the West African sub region. VALCO's operations began in 1967 with three cell lines. By 1974, two other cell lines had been added to increase its total production capacity. Each cell line, also known as a potroom, houses hundred cells.

VALCO's five cell lines have a total production capacity of 200,000MT of aluminium per year. However, aluminium production averages to about 70% of installed capacity since it began operations. This has largely been due to unavailable electric power supply. VALCO employs over 700 employees for its operations. VALCO's operations can be grouped under three main units. These are: Production, Human Resource and Administration and Supporting Services. At the time of this study, only one of the five cell lines was in full operations although processes had started in earnest to begin a second line and rump it up.

3.2 Study design

This research was conducted using a cross-sectional retrospective study design

3.3 Study variables

3.3.1 Outcome variables:

Pre and Post shift fluoride levels in urine

3.3.2 Independent variables:

The independent variables included:

Demographic variables:

1. Age
2. Years of service
3. Job category
4. Use and availability of PPEs

3.4 Sample size

The sample size for the study was estimated using the Slovin formular (1960). The population of potroom workers, N was extracted using data from the human resource department. The margin of error for the study was set at 5%.

$$n = \frac{N}{1 + N\varepsilon^2}$$

n = Sample size

N = Population size (87)

ε = Margin of error (5%)

$$n = \frac{87}{1 + 87(0.05)^2}$$

$$n = \frac{87}{1 + 87(0.0025)}$$

$$n = \frac{87}{1.2175}$$

$$n = 71.46$$

The minimum sample size for this study was estimated to be 71. An estimated 20% non-response rate was calculated and added to the minimum sample size. Altogether, a sample size of 82 potroom workers was used for the study. Sample containers were dispensed to 85 potroom workers.

3.5 Study population

The study participants were potroom workers of VALCO.

3.5.1 Inclusion criteria

All permanent potroom workers of VALCO who gave their consent to be part of the study were included.

3.5.2 Exclusion criteria

Temporal potroom workers such as service personal, management members and non-management employees from other units who spend less than half of their entire shift period doing potroom work were excluded from the study. Maintenance employees and staff from cell repairs were also excluded.

3.6 Sampling Method

The study participants were conveniently sampled. This was as a result of their busy work schedule and their 12 hours rotational system. As such, all qualified potroom workers who agreed to be part of the study were recruited into the study. These workers worked as members of a crew. There were four crews namely; crew A, B, C and D. Each crew had an average of twenty persons. The crews worked in a 12 hours shift system. Crew members were involved in potroom tasks such as crane operations, metal tapping and pot tending. These duties place the crew members at risk of fluoride exposure.

The morning shifts began at 7am and ended at 7pm while the night shifts began at 7pm and ended at 7am. Those who came for the night shift, after their shift ended after 12 hours were given three days off. Participants were conveniently sampled till the required sample size was obtained. On the very first day of the morning shift, urine samples were taken for analysis as preshift urine. The post shift urine were also taken on the last day of duty after closing from the 12 hours shift period.

3.7 Data collection

Data was collected in three (3) parts.

1. Data extraction
2. On-site urine sampling
3. Non-participant observation

3.7.1 Data extraction

A checklist (Appendix 3) was designed by the researcher and used to extract data on all employees working in the potroom from the human resource department's database. Data were collected on socio-demographic characteristics, number of service years and potroom task or job. The data was extracted from the health records of the VALCO hospital using a trained assistant into a Microsoft excel spreadsheet and was cleaned of errors. Where there was need for validation, the ICT unit was contacted to validate the information obtained.

3.7.2 On-site urine collection

Two samples of urine were collected from each participant for the fluoride analysis. The samples were collected in 150ml propylene bottles. The pre shift samples were collected at the beginning of each shift. This was done on the first day of the shift after an off duty for 72 hours. Potroom workers who were called in for overtime responsibilities during the 72 hours off duty had their sample collection deferred to a later date. The post shift urine samples were also collected on the last duty day after a 72 hour duty period. The participants were given the sample bottles as they went into the locker house after closing from duty. They were instructed to fill the sample bottles with 50mls or more of their urine and to return the bottle at a central collection point.

3.7.3 Non-participant observation on PPE use

A non-participant observation was also conducted on the use of personal protective equipment by the respondents. This was conducted on the teams on the last day of each morning shift duty. The non-participant observations were conducted in the potroom while they carried out their normal duties in the potroom. Using a checklist, the potroom workers were observed for the availability, condition and correct use of their PPEs. Though the teams run two shift duties per day, one day and one night, no observations were conducted on the night shift. All observations were conducted during the day shift. All observations made were documented on the check list and tallied at the end of the observatory period. Where clarification was needed, the safety officer was contacted for explanation.

3.8 Laboratory analysis of urine samples

The samples were transported to the technical laboratory and preserved in a refrigerator at 4 °C and were analyzed within 24 hours of collection. For each sample, 50mls sample was measured into a 200ml plastic beaker and 50mls of TISAB II was added. A magnetic stirrer bar was placed in the sample and the resulting solution was placed on a magnetic stirrer. Each solution was stirred on the magnetic stirrer for a minute.

An ion selective electrode of a pre-calibrated Mettler Toledo meter (Model: Mettler 4, USA INC) was rinsed with deionized water. The electrode was blotted dry and immersed in the stirred solution. The electrode was kept in the stirred solution until the reading became stable for 5 seconds. The reading was recorded as the fluoride level for that sample and recorded in parts per million (ppm).

3.9 Data processing and analysis

The data collected were entered into Microsoft Excel 2016 and then imported into Stata software version 15 for statistical analysis. Descriptive statistics such as frequency, percentages, means and standard deviations were used in describing the demographic and background characteristics of the study participants. Normality of data was checked using Shapiro francis test before analysis. Bivariate analysis using Chi square test of independence was performed to test the significant of the associations between independent variables and preshift and postshift urine fluoride concentrations. Multiple logistic regression was carried out on the factors that were statistically significant at the bivariate level. Crude and adjusted odds ratio were computed and statistical significance was set at $p < 0.05$. The student's t-test was conducted to test for statistically significant difference between the pre and post shift urine fluoride levels.

3.10 Quality control

To ensure data quality, a standardized data extraction sheet was designed and printed for the data extraction. An undergraduate was engaged and trained for a day on the use of the data extraction sheet. The data collected was further vetted randomly to ensure completeness.

For quality control purposes for the lab analysis, the electrode was prepared before each day's use. The electrode was prepared by first removing the protective shipping cap from the sensing element. The cap was then put for storage. The electrode was filled with Ion Electrolyte Reference filling solution. The flip sprout cap on the filling solution bottle was installed to a vertical position. The sprout was inserted into the filling hole on the

outer body of the electrode and a small amount of filling solution was added to the reference chamber. The electrode was inverted to moisten its O-ring and returned to the upright position. The electrode was held in the researcher's dominant hand and the thumb was used to push down on its cap to allow some few drops of filling solution to drain out. The cap was then released and the sleeve was observed as it returned to its original position. More filling solution were then added to the electrode to mark up to the filling hole.

After the electrode preparation, the ion selective electrode meter was then calibrated using three calibration standard solutions (0.1mg/L, 1.0mg/L and 10.0mg/L). The solutions were prepared from a standard fluoride solution of 100mg/L concentration taking into account the expected fluoride ranges for the urine samples. A 1:1 solution of TISAB 11 to solution were prepared for standards and samples.

The prepared electrode was immersed into the lowest standard solution with concentration of 0.1mg/L of fluoride. The calibration was then started on the ion selective electrode meter. The end point was determined after the reading had stopped blinking. The electrode was taken out of the standard solution and rinsed. The electrode was blotted dry to protect the sensitive sensor. The process was repeated for the other standards (1.0mg/L and 10.0mg/L). After calibrating for all three standards, a graph was generated using the readings of the three standards. This graph was plotted using the scores of the three standards because using just two standards will not give an authentic calibration curve.

3.11 Ethical Considerations

Ethical approval for this study was obtained from the Ethics Review Committee of the Ghana Health Service before the commencement of the study. Permission was also sought from the Management of VALCO. Participants were informed of the reasons, benefit, risk and the process for conducting this study. Their permission were sought before recruiting them into the study.

3.11.1 Access and approval of study area

The principal investigator made a reconnaissance visit to the study area to notify the management of VALCO about the intention to conduct the study. An introductory letter was obtained from the Head of Department, School of Public Health, College of Health Sciences, University of Ghana and sent to the Management of the Company for permission to conduct the study. Subsequently, a copy of the approval letter from the Ghana Health Service Ethical Review Committee was also sent to the authorities.

3.11.2 Privacy and Anonymity

In order to ensure privacy and anonymity, the urine analysis were conducted in a private room and participants' names were not mentioned in the report of the study. The information gathered on participants were kept strictly confidential between the principal investigator and the study participants.

3.11.3 Compensation

Participants were not given any monetary compensation.

3.11.4 Risks and Benefits

Apart from the time that was lost by study subjects during urine sample collection, there was no risk or cost associated in participating in the study. Participants would not gain any direct benefits. However, it is expected that the results of the study may contribute towards health policy decisions which may be beneficial to both the study participants, VALCO, the government and the principal investigator.

3.11.5 Voluntary withdrawal

All eligible respondents were informed accordingly that their participation in the study was purely out of their free will. They could also decide to withdraw at any point of the data collection.

3.11.6 Informed Consent and Consenting process

Informed consent was obtained from participants before commencement of the study. Respondents in the study were approached individually to explain the objectives of the study to them and in order to seek their consent. The decision to take part in the study was absolutely voluntary and refusal to take part would not affect the relationship between the participant(s) and the researcher. In addition, respondents were made to sign a written consent form after a detailed explanation to them before they were allowed to participate in the study.

3.11.7 Data storage and usage

Data collected in this study was strictly used for research purposes. The data were stored with passwords on electronic media and it was safely locked in boxes. Anonymity was

ensured in dissemination of findings from this study since participants were not identified by their names.

3.11.8 Declaration of conflict of interest

The researcher as the principal investigator does hereby declare no conflict of interest in this study.

3.11.9 Funding of the study

This study is in partial fulfillment of requirements towards the award of a Master of Public Health (MPH) degree at the School of Public Health, College of Health Sciences, University of Ghana, Legon. Hence, there is no funding from any source and all estimated cost of the study was borne solely by the principal Investigator.

3.11.10 Strengths and Limitations of study

This study has helped brought to fore the levels of exposure to fluoride among potroom workers at VALCO which have significant implication for policy interventions and strategies on public health. The results of this study however is limited to the extent that, no causal relationship was established among study variables. The study also used secondary data sources for the independent variables since Management of VALCO did not allow the researcher to interview the participants. This could have given the researcher more opportunity to look out for signs and symptoms experienced by participants and other variables which could have strengthened the outcome of the study.

CHAPTER FOUR

RESULTS

4.1 Demographic characteristics of potroom workers

The background information on the potroom workers were as shown in Table 1. Out of a total of 85 urine sample bottles issued to potroom workers for their pre shift and post fluoride concentration, 82 (96%) gave out urine samples. All the participants in the study were males and their ages ranged from 22 to 66years. Majority (40.2%) of the participants were between the ages of 20-39years with mean age of 46.4 ± 1.5 . Most respondents (93.9%) had attained secondary/vocational level. Majority of the workers, 36 (43.9%) had less than one years of service experience in the potroom.

Table 4.1: Demographic characteristics of study subjects

Variable	Frequency (N=82)	Percentage (%)
Age (Years)		
20-39	33	40.2
40-59	28	34.2
>59	21	25.6
Mean \pm SD(95% CI:43.3-49.36) 46.4 \pm 1.5		
Educational Level		
Secondary/vocational	77	93.9
Tertiary	5	6.1
Years of Service		
<1 year	36	43.9
1-5 years	24	29.3
> 5 years	22	26.8
Mean \pm SD (95% CI:1.65-2.01) 1.8 \pm 0.09		
Job category		
Cell operator	27	32.9
Taper Setter	27	32.9
Crane Operator	17	20.8
Taper setter trainee	11	13.4
Use of PPEs		
Use	76	92.7
Non –use	6	7.3

4.2 Pre and post shift urine fluoride concentrations

The analysis revealed that 9.8% (95% CI: 3% - 16%) of potroom workers had their preshift fluoride levels in urine greater than 4ppm. The mean preshift urine fluoride levels was 0.98 ± 0.32 . However, with regards to post shift, all 82 (100%) participants had their post shift urine fluoride levels below 7ppm [1.48 ± 0.17 (95% CI = 1.15-1.837)] . The value ranged from a minimum of 0.016ppm and a maximum of 6.104ppm (Table 4.2). There was a statistically significant difference between preshift and post shift urine fluoride concentrations at 95% confidence level (Table 4.2).

Table 4. 2: Comparing pre and post shift urine fluoride concentrations using the student's paired sample t-test

Variable	N (%)	Range/ppm	Mean \pm SD	ACGIH Acceptable limit	p-value
Pre-shift Fluoride		0.08 - 6.52	0.98 ± 0.32	4ppm	< 0.001*
≤ 4ppm	74 (90.2)				
> 4ppm	8 (9.8)				
Post-shift Fluoride		0.016 - 6.104	1.48 ± 0.17	7ppm	
≤ 7ppm	82(100.0)				
> 7ppm	0 (0.00)				

***p -value obtained from a student's paired sample t-test**

4.3 Pre and post shift urine fluoride by job category

Table 4.3 shows the comparison between the pre and post shift urine fluoride concentration by job category. Generally, the post shift urine fluoride concentrations were higher than their corresponding pre shift concentrations for the different job categories of the potroom workers. The job type with the highest mean preshift and postshift fluoride concentrations were the taper setters with mean value of 0.94 ppm and 1.22 ppm respectively. The taper setter trainees recorded the lowest preshift and postshift urine fluoride levels with mean value of 0.46 ppm and 0.73 ppm respectively (Table 4.3).

Analysis of variance (ANOVA) at 95% confidence level showed that the fluoride level by job category was not statistically significant ($F = 2.142$, $p = 0.766$).

Table 4. 3: Mean levels of pre and post shift urine fluoride concentrations by job category

Category	Preshift Mean \pm SD	Post shift Mean \pm SD	p-value
Cell operator	0.82 (0.18)	0.98 (0.32)	0.766
Taper setter	0.94 (0.15)	1.22 (0.06)	
Crane operator	0.81(0.11)	1.17 (0.04)	
Taper setter trainee	0.46 (0.02)	0.73(0.01)	

p -value obtained from one way ANOVA

4.4 Association between background characteristics and urine fluoride concentrations

4.4.1 Bivariate Analysis

A bivariate analysis was performed to examine the relationship between socio-demographic and other related factors and preshift concentrations of fluoride in urine. The results revealed that, there was an association between job category and fluoride concentrations in urine at 95% confidence level. Potroom job category was significantly associated with fluoride concentrations in urine ($p < 0.043$). Other demographic variables such as age, educational level and years of service were assessed but were found not to be significantly associated with fluoride concentration in urine (Table 4.4).

With respect to post shift fluoride in urine concentration, all 82 participants had their post shift urine fluoride concentration below the recommended allowable limit of 7ppm and therefore the researcher did not conduct any associations between demographics and background characteristics and post shift urine fluoride concentrations

Table 4. 4: Association between background characteristics and levels of preshift urine flouride levels among potroom workers at VALCO

Variable	Pre-shift Urine fluoride Conc.			χ^2	p-value
	Low	(%)	High		
Age group				1.87	0.532
20-39	30 (90.9)	3 (9.1)	33(100.0)		
40-59	24 (85.7)	4 (14.3)	28(100.0)		
59+	20 (95.2)	1(4.8)	21(100.0)		
Job category				5.82	0.043
Cell operator	25 (92.6)	2 (7.4)	27(100.0)		
Taper setter	24(88.9)	3(11.1)	27(100.0)		
Crane operator	15(88.2)	2(11.8)	17(100.0)		
Taper setter trainees	10(90.9)	1 (9.1)	11(100.0)		
Years of service				2.37	0.932
<1 Year	32 (88.9)	4 (11.1)	36 (100.0)		
1-5 Years	22 (91.7)	2 (8.3)	24 (100.0)		
>5 years	20 (90.9)	2 (9.1)	22 (10.0)		
Educational level					
Secondary	71(89.8)	8(10.2)	79(100.0)	4.35	0.562
Tertiary	3 (100.0)	0 (0.0)	3 (100.0)		

Multiple logistic regression was conducted on the factors that were statistically significant at the bivariate level. Job category was found to be statistically associated with preshift fluoride levels in urine at the multiple logistic regression analysis level ($P < 0.05$) (Table 4.7). Specifically, the odds of urine fluoride concentration was 21% times higher among Tape setters working category compared to the cell operators (AOR=1.21.; 95% CI=1.01-4.32) (Table 4.5).

Table 4.5: Multiple Logistics regression of the factors associated with urine fluoride concentration

Variable	p-value	cOR (95%CI)	AOR (95%CI)
Job category			
Cell operator		1.0 (ref)	1.0 (ref)
Taper Setter	0.042*	1.16 (0.26-2.38)	1.21 (1.01-4.32)
Crane Operator	0.368	0.63 (0.41-3.69)	0.82 (0.47-3.66)
Taper Setter trainee	0.978	0.72 (0.31-3.56)	0.82 (0.25-3.45)
Age group			
20-39		1.0 (ref)	1.0 (ref)
40-59	0.295	1.66 (0.34-8.17)	3.26(0.36-29.83)
59+	0.422	0.50(0.05-5.15)	0.29 (0.01-5.84)
Years of service			
<1 Year		1.0 (ref)	1.0 (ref)
1-5 Years	0.752	0.73 (0.12-4.32)	0.57 (0.75-4.38)
>5 years	0.236	0.80 (0.13-4.78)	0.26 (0.02-2.99)

4.5 Assessing and describing PPEs use among the potroom workers

From a non-participant observation at the potroom, all the potroom workers were identified to have the full set of recommended PPE for the various potroom jobs. Among the observed potroom workers, the following were the recommended PPEs for the potroom task: winter liners, ear plugs, face shield, respiratory filter mask, Khaki/Cotton shirt and pants, leather apron, heat resistant gloves, productions boots and spats. The winter liners were observed to be used mainly by cell operators, taper setters and taper setter trainees. The winter liners protected the neck from molten metal, alumina and fluoride fines from coming into direct contact. They were all observed to be in good condition. All the potroom workers had ear plugs. They were all seen to have the ear plugs while working in the potroom. Two types of face shields were observed to be in use, a green face shield and plain and colorless face shield. The plain and colorless face

shields were worn by the cell operators to prevent particles from settling on their face during carbon anode cleaning while the green face shields were worn by the taper setters and taper setter trainees (Table 4.6)

Table 4.6: Assessment of PPEs use among potroom workers

Type of PPE	Availability	Condition of PPEs	%Usage
Respiratory Mask (Hydrogen Fluoride)	Yes	Good	100%
Hot Mill Gloves	Yes	Good	100%
Apron	Yes	Good	100%
Spat	Yes	Good	100%
Face Shield	Yes	Good	100%
Winter Liner	Yes	Good	100%
Cotton Shirts	Yes	Good	100%
Cotton Pants	Yes	Good	100%
Production Safety Shoes	Yes	Good	100%
Ear Plugs	Yes	Good	100%

CHAPTER FIVE

DISCUSSION

In this study, all potroom participants were males. This high male dominance is consistent with other findings in the aluminium industry. The potroom work has traditionally been a male-dominated work environment. As a result most of the previous studies published on potroom workers have been mainly focused on men (Susheela et al., 2014). The potroom work environment is a male dominated environment. A study conducted in Western Norway by Soyseth & Kongerud, (1992) among a potroom population of 380 had a male population of 97 %. Similarly a multicenter study involving 1,805 potroom workers from 7 Norwegian aluminium reduction plants by Kongerud et al., (2018), had only 7% (126) females which are consistent with the findings obtained in this study. Until recently, the potroom work environment was a physically demanding one. There were various environmental contaminants thought to be unsafe for women especially those in the reproductive age group. The unfavorable contaminants in the potroom environment included electromagnetic radiation, particulates, PAH, fluorides, heat and excessive noise (Kongerud et al., (2018). These contaminants were also believed to be very unsuitable for women's health. Existing prejudices were also against women for venturing into physically demanding jobs such as the potroom work. Men were thus competitively favored. This situation has persisted though efforts are being made to make the work environment friendlier and safer for all workers. Newer technologies and process improvements are being employed to realize this dream. Though most of the potroom tasks have been automated in newer smelters

there still exist the traditional view of the potroom being a relatively high risk and labor intensive work environment for women especially those in the reproductive age group.

In this study, the overall proportion of potroom workers with high concentration of preshift urine fluoride concentration was 9.8% (95% CI: 0.03-0.16). This is consistent with the findings of Shisoka & Litali, (2015) where the proportion of workers with high concentrations of fluoride in urine during preshift was 6%. This finding is lower compared to a similar study carried out in Nigeria where 17.2 % of respondents reported to have high fluoride concentrations of urine fluoride in an aluminium smelter industry (Adelekan et al., 2014). An even higher proportion (25.5%) was reported by Walle & Alamrew (2014) in a study among male aluminium factory workers in Bahir Dar which was attributed to high exposure to fluoride during the smelting.

The potroom workers all had their post shift urine fluoride levels below the ACGIH Biological Exposure Index. This finding is in agreement with a study by Seixas et al., (2010) where the pre and post shift fluoride for potroom room workers who were followed for a period in a prebake technology plant did not exceed the ACGIH biological exposure index. This is an indication that they were not highly exposed to fluoride probably from the controlled potroom environment. The high levels obtained however for participants during the preshift urine samples could partly be attributed to other external sources such as; the consuming of water with high fluoride concentrations or using substances such as some consumer products with high fluoride contents. Consumption of substance with high levels of fluoride is another important route of entry of fluoride into the body. People may also be exposed to fluoride in food, dental products and drugs. People, who chew tobacco, ayurvedic digestive tablets; or eating of black rock salt, laced snacks or

pickles, consumption of readymade spices containing black rock salt, black tea (without milk), or use of dental products have also been found to predispose workers to have high fluoride levels in their preshift urine in most studies (Morton et al. 2011; Kongerud et al., 2018). This might have accounted for the high level of preshift urine fluoride in some potroom workers in this current study.

In this study, the job category of potroom workers significantly influenced their preshift urine fluoride levels. The age and service duration in years however did not significantly influence the pre and post shift urine fluoride. These findings are consistent with the work of Seixas et al., (2010) who also did not find any statistically significant association between age and number of years of service of potroom workers in a study conducted in aluminium industry in Iran.

All potroom workers observed in this current study had the recommended PPE. This included the following winter liners, face shield, respiratory mask, ear plugs, cotton/khaki shirts and pants, apron, production shoes and a spat. The PPEs were also observed to be in good condition. Results of this study indicated that the potroom workers had adequate knowledge of occupational hazards and safety practices. Also, the management of VALCO were enforcing the safety rules and regulations to safeguard the health of workers. This finding is supported by a cross-sectional study which found high level of PPEs use among potroom workers in aluminium industry (Henrotin et al., 2017). Considering the high level of availability and use of PPEs among potroom workers, it is expected that there would be low prevalence of exposure to fluoride among potroom workers which corroborates the results obtained for the post shift urine fluoride levels. But in this current study, since high levels of preshift urine fluoride was recorded in some

participants, it suggests that sustenance of use of PPEs may prevent them from direct exposure from post shift, however, other external factors with high fluoride content may work together to increase the levels of urine fluoride.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

This study has demonstrated that the proportion of potroom workers with high levels of fluoride in preshift urine is very low. Potroom workers are exposed to acceptable levels of potroom fluorides as post shift fluoride levels in urine were all within the recommended limits set by OSHA. There was a statistically significant difference in preshift and post shift urine fluorides among the workers. The job category was the factor found to be significantly associated with preshift urine fluoride levels. The study therefore rejects the null hypothesis that there is no significant difference between pre and post shift urine fluoride concentrations. The study also fails to reject the null hypothesis that there is no significant effect of fluoride levels on pot room workers at VALCO. The overall conclusion is that health and safety practices and support need to be given to potroom workers in order to address any unforeseen health effects of fluoride in the long term.

6.2 Recommendations

- Periodic monitoring of fluoride levels of all workers in the potroom should be enforced especially tape setter trainees and crane operators to detect and protect workers from high levels of exposure.
- Future studies should look at the fluoride levels in the potroom environment.

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APPENDICES

Appendix 1: Participant's Information Sheet

TITLE OF STUDY: ASSESSMENT OF URINE FLUORIDE CONCENTRATION AMONG POTROOM WORKERS OF VOLTA ALUMINIUM COMPANY, TEMA

INTRODUCTION

I am Dr. Bernard Nii Torgbor, a student of the School of Public Health, University of Ghana. This study is being conducted as part of the requirements for the award of Masters in Public Health.

My contact details are as follows: P. O Box 625, Tema. Mobile 0501619342 email bernard.torgbor@valcotema.com

BACKGROUND OF RESEARCH

Aluminium is produced from alumina through an electrolytic reaction in carbon lined steel vessels called pots. The pots are housed in an area called potroom. At 960°C alumina is dissolved in molten cryolite electrolyte bath. Fluoride fumes and gases are emitted from the electrolyte bath which may be inhaled or ingested into the human body. At certain amounts in the human body, fluoride is associated with some occupational diseases such as asthma, muscle and joint pains and abdominal pains. The amount of fluoride in the body can be estimated from urine.

NATURE OF RESEARCH

This is a biomedical research. The aim of this study is to determine the fluoride exposure among potroom workers by measuring the amount of fluoride in their urine and also to determine whether this falls within the international standards (ACGIH biological exposure index).

You will be expected to provide two sets of urine samples, Pre and Post shift urine samples. These will be collected using 150ml polypropylene sample containers with snug fitting polyethylene caps. The pre shift sample will be collected before the start of your 12-hour shift (after being off-shift for a 72hour period). The post shift sample will be collected soon after closing from a 12-hour shift. The samples will be transported to the VALCO Technical laboratory and preserved in a refrigerator at 4°C. The fluoride content will be estimated in the lab using the Mettler Toledo meter

PARTICIPANTS INVOLVEMENT

- **Duration / what is involved:** You will be expected to provide 50mls (7 dessert spoonfuls) of urine after a 72 hours off-shift period and soon after a 72hours duty-shift.
- **Potential Risks:** There are no risks or harm in this study however there is a possibility of discomfort in carrying your urine to the collection point.
- **Benefits:** There will be no direct benefit to you. The outcome of the study may be shared with your company's safety managers who may implement some of the recommendations.
- **Compensation:** There will be no remuneration for participation
- **Confidentiality:** There will be no personal identifiers to single out individuals. The data collected will be locked up in a cabinet. This data will not be shared with anyone.

- **Voluntary Participation/Withdrawal:** Participation is voluntary and you may withdraw from the study at any time without giving reasons. You will not be made to pay any penalty should you choose to withdraw at any point from the study.
- **Outcome and Feedback:** You will not be given any feedback. However the outcome of the study may be shared with your safety managers to enhance the safety process
- **Funding Information:** The study is wholly sponsored by the principal investigator
- **Conflict of interest:** The data generated from this study will be solely for the use of this study. No other person or persons will have access to this data.

In case you need further details and/or clarifications, you may contact:

Dr. Bernard Nii Torgbor, VALCO Hospital. Mobile 0501619342 or email bernard.torgbor@valcotema.com or The Ethics Committee Administrator on 0302687821/0302682709

Appendix 2: Consent Form

PARTICIPANTS CONSENT

I voluntarily accept to be part of this study. I certify that I have read and understood the information sheet and all my questions have been answered satisfactorily.

.....

(Signature or thumbprint of Participant)

.....

(Date)

INVESTIGATOR'S STATEMENT

I certify that the participant has been given ample time to read and learn about this study. All questions and clarifications from the participant have been duly addressed.

.....

(Signature of Investigator)

.....

(Date)

Appendix 4 :Non Participant Observatory Checklist For Ppe

ITEM	Are the following PPEs worn and in good condition?	Yes	No	N/A	Comment
1	Helmet				
2	Safety glasses with side shields				
3	Shoe and socks				
4	Shirt				
5	Pants and Belts				
6	Spats				
7	Ear plugs/Mufflers				
8	Respirator				
9	Cotton cap				
10	Cutting/welding shield				
11	Gloves(Hot mill, Leather, MCTE)				
12	Face shield				
13	Apron				
14	Full body Harness				
15	Coveralls(disposable/jumpsuits)				
16	Others				