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EFFECT OF E-WASTE ON COGNITIVE FUNCTIONS OF JHS 1 PUPILS IN SCHOOLS AROUND E-WASTE SITE AT AGBOGBLOSHIE

BY

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DECLARATION

I, AGBEKO MAWUTOR KWAME, declare that except for the citing of other people's investigations which have been duly acknowledged, this work is the result of my own original research undertaken under supervision, and that this dissertation, either in whole or in part has not been presented elsewhere for another degree.

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DEDICATION

This project work is dedicated to my wife and children Shelter, Rejoice and Kenneth.

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ABSTRACT

Background: Disposal of electronic waste is an emerging global environmental and public health problem. The recycling of electronic waste by open burning releases a complex mixture of toxicants containing oxides of inorganic particles of metals which disperse into the environment to affect the health of pupils attending schools located around Agbogbloshie e-waste site. Hazardous inorganic metals such as Lead (Pb), Manganese (Mn), Cadmium (Cd), Chromium (Cr) and Nickel (Ni) found in e-waste have strong neurodevelopment and neurobehavioral effects on cognition especially in children. Studies have associated e-waste recycling with several adverse cognitive health outcomes such as low intelligence quotient, poor memory, attention deficit and learning disability among school children, but no such studies have enumerated such effects of e-waste on school pupils in Ghana.

Aim: This study assessed the body burden of heavy metals in blood Lead, Manganese, and urine Cadmium, Chromium and Nickel and cognitive function of JHS 1 pupils in schools around e-waste processing site at Agbogbloshie.

Methodology: A cross-sectional study was carried out from May to June 2015 among 50 pupils. Adapted form of structured toxicity questionnaire was used to collect data on poor memory, confusion, poor concentration, difficulty in making decision, stuttering, slurred speech, learning disability and attention deficit. Intelligence quotient was measure using the Wechsler Intelligence Scale for Children-Fourth Edition. Urine and blood were sampled into vacutainers. At the time of reporting the study data was available for only 21 pupils. The proportion of symptoms of cognitive well-being was calculated. Mean and standard deviations of heavy metals and IQ were computed. Multivariate linear regression analysis was used to assess the association between the heavy metals and Full-Scale IQ.

Results: The mean concentrations (SD) of heavy metals in blood and urine samples of the pupils were 63.3(28.3) µg/L, 11.55(4.7) µg/L, 0.32(0.04) µg/L, 5.47(1.3) µg/L, and 0.37(0.03) µg/L for Pb in blood, Mn in blood and Cd, Ni and Cr in urine respectively. The mean IQ was 69 (3.28). There were statistically no significant associations between the heavy metals and Full-Scale IQ.

Conclusion: This study revealed that pupils attending schools near the e-waste site were exposed to heavy metals. Their mean intelligence quotient was below average according to Wechsler classification of intelligence quotient. Attention deficit, difficulty in making decision, confusion and learning disability were also common among the pupils.

Keywords: Cognitive function, Cognitive health outcome, Cognitive well-being, E-waste, Intelligence Quotient (IQ), Heavy metals, Neurotoxicity.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ATSDR - Agency for Toxic Substances and Disease Registry

BLL - Blood Lead Level

BMn- Blood manganese

BPb- Blood lead

CRT- Cathod Ray Tube

Cd – Cadmium

CDC - Center for Disease Control

Cr – Chromium

DVD- Digital Video Disc

EPA - Environmental Protection Agency

E-WASTE - Electronic waste

H-RCS AAS- High Resolution Continuum Source Atomic Absorption Spectrophotometry

IQ - Intelligence Quotient

Mn- Manganese

MMWR - Morbidity and Mortality Weekly Report

OEHHA- Office of Environmental Health Hazard Assessment

Pb – Lead

ppm- Parts per million

SD- Standard Deviation

SVTC - Silicon Valley Toxics Coalition

UNEP - United Nations Environmental Program

UCd- Urine cadmium

UCr- Urine chromium

UNi- Urine nickel

US - United States

VCRs- Video Cassette Recorders

WHO- World Health Organization

DEFINITION OF TERMS

E-waste: end of life unwanted, obsolete or unusable electronic products such as computers, computer peripherals, televisions, Video Cassette Recorders (VCRs), Digital Video Disc (DVD) Players, hand cell phones and stereo equipment which is dependent on electrical currents or electromagnetic fields in order to work properly comprising of toxic metallic and plastic components.

Intelligence Quotient (IQ): measure of individual cognitive ability using an appropriate standardized scale of choice to obtain scores that quantifies human intelligence.

Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV): a standardized individually administered intelligence test for children between the ages of 6 to 16 inclusive; that can be completed to generate IQ scores which represent a child's cognitive ability.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Rapid technological advancement, frequent replacement of outdated software, changes in audio components and planned obsolescence have resulted in a fast growing surplus of electronic waste (e-waste) around the world (Lundgren, 2012). Disposal of electronic waste is an emerging global environmental health problem because of massive volumes generated and the absence of management policy as well as recycling facilities in many countries (Ogunseitan et al., 2009). E-waste has become the most rapidly growing segment of the metropolitan and municipal waste stream in the world [Silicon Valley Toxics Coalition (SVTC), 2001]. As a result, environmental contamination by e-waste processing activities has become a major health problem and concern worldwide. Although the environmental and health problems posed by e-waste recycling have been solved in high income countries, these problems still exist in low and middle income countries. One of the biggest issues is the exposure to oxides of toxic metals which are by-products of e-waste recycling through the burning of insulated wires from dismantled parts. As stated by the U.S Environmental Protection Agency (EPA), the stream of e-waste is growing two to three times the rate of any other source of waste (U.S. EPA, 2008). Estimates also suggested by the United Nations Environmental program states that by the year 2020, the domestically generated e-wastes as a consequence of aging televisions will increase two folds, while that from computers will multiply five times, and those from cell phones will multiply 18 times the current volumes of e-waste (UNEP, 2005). The recipients of these e-wastes are developing countries (UNEP, 2009). Globally, an estimated 20-50 million metric tons of e-waste are generated yearly (Hussain and Mumtaz, 2014) with 13 percent of the global e-waste weight that is churned out

recycled mostly in cities of developing countries such as Accra-Ghana, Lagos-Nigeria, Delhi and Bengaluru-India and Taizhou and Guiyu-China (Davis and Heart, 2010) shown in **Figure 1** below.

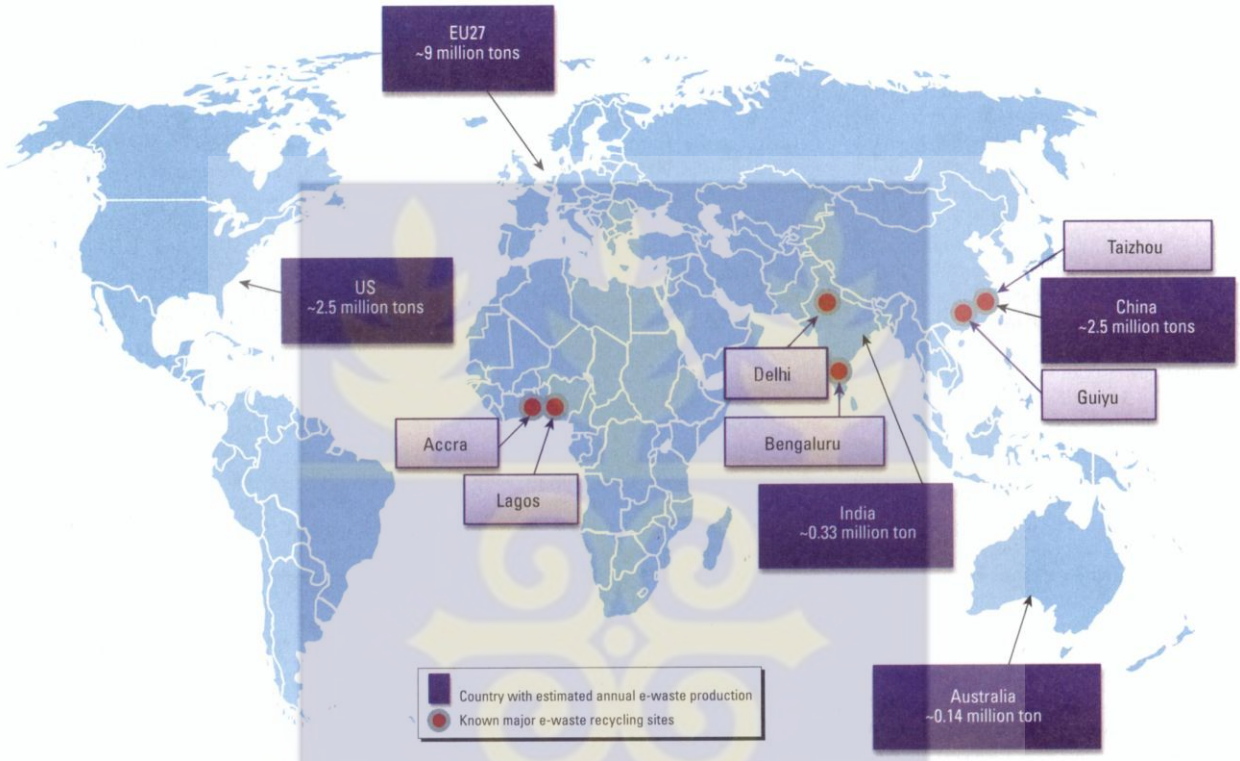

Figure 1- Estimated annual production of e-waste and major recycling sites.

Source: Adapted from Davis and Heart, 2010.

*Estimates may not reflect current production volume. In addition, the estimates exclude Japan, Russia, and Canada. The number of recycling sites is by no means complete but may represent major processing regions of e-waste.

Ghana has seen a consistent increase in e-waste inflow from Europe and the U.S.A. In Ghana, the major e-waste receptor site is at Agbogbloshie. It is the most polluted site in West Africa and among the top 10 most polluted places in the world (Feldt et al., 2013; Blacksmith Institute, 2013). In 2009 alone, 215000 tons of e-waste was imported into Ghana (Feldt et. al., 2013).

At Agbogbloshie, informal collectors are involved in the collection of outdated and discarded electronic appliances and contraptions that have passed time of use or usefulness from homes, offices and from electronic repair shops. Collected waste is sold to informal recyclers who dismantle, crush or subject insulated e-waste wires to open burning to retrieve valuable but toxic metals. Electronic devices may contain several toxic substances. An old Cathode Ray Tube (CRT) television may also contain about 1.5 kg to 3 kg of lead, and a CRT computer monitor may contain about 0.5 kg of lead (Chen et al., 2011). Pb has been found in printed circuit boards and transistors whereas Mn is noted in transistors, diodes, cell phones, and printed circuit boards (e.g., switches, relays) (Ramesh et al., 2007). Lead exposure among school-age children remains an important public health issue around the world due to related cognitive development impairment and associated deficits in intellectual ability (Bowers and Beck, 2006; Chen et al., 2007; Mazumdar et al., 2012). Behavioral problems due to lead exposure may persist into adolescence and even adulthood (Fergusson et al., 2008; Wright & Baccarelli, 2008; Mazumdar et al., 2011).

Open burning of e-waste releases a complex mixture of toxic gases and fumes (Chi et al., 2011, Feldt et al., 2013) containing for example oxides of lead, cadmium, and mercury and organic components such as polybrominated diphenyl ethers (PBDE), furans, dioxins and polyaromatic hydrocarborns (PAH) which disperse into different media such as water, soil and air (ATSDR, 2008; Agyarko et al., 2010; Atiemo and Fosu, 2012). Common exposure routes of toxicants from e-waste recycling are by inhalation, dermal contact and ingestion, and the medium of exposure of chemical substances is through water, food, soil and air (Harris & MacCartor., 2011). At Agbogbloshie, many of the recycling sites have operated for more than ten years, and aggregate exposure in the neighbourhood is expected to be typically high as

contamination extends to the surroundings of e-waste recycling areas (Tang et al., 2010; Wang and Guo 2006).

Several health effects have been associated with e-waste exposure and this includes brain, respiratory, hormonal disorders, kidney and bone problems (Brune et al., 2013). Among pregnant women living near an e-waste site, birth defects, preterm delivery and low birth weight have been observed in their infants (Asante et al., 2012). Mental problems, attention deficit and behaviour problems have also been reported in children living near e-waste sites (Grant, 2013). It is becoming increasingly evident that the incidence of neurodevelopment toxicity is dependent on co-exposure to multiple neurotoxicants (Bellinger, 2008; Kim et al., 2009). Mn is a potentially hazardous agent which was reported to affect cognitive function in children (Bouchard et al., 2011) and was associated with low IQ scores when co-exposed with lead (Kim et al., 2009). However, few studies have assessed the effects of multiple exposures to heavy metals on IQ or health (Bellinger, 2008).

In Ghana, high levels of heavy metals and other pollutants have been reported in soil, water and air in communities close to the e-waste recycling site (Cannavaro et al., 2011; Feldt et al., 2013). But the adverse effect in the human population is unknown (Chen et al., 2011). Extensive literature has already documented the deleterious effects of heavy metal toxins on the human brain and nervous system. These toxins however, represent only a fraction of the environmental hazards that may pose harm to cognitive ability in humans. Lead, manganese, cadmium, chromium, nickel and organic compounds are components of polluted air exposed. All have the potential to damage brain functioning yet remain understudied. In order to provide comprehensive data for the prevention of decreased cognitive ability of pupils who attend schools located at the e-waste recycling site, it is important to initiate bio-monitoring programs

in developing countries where e-waste recycling is done at the informal level with rudimentary methods.

The study was designed to investigate the relationship of co-exposure of selected heavy metals of known neurotoxicity which are components of the by-products of e-waste on the cognitive function of pupils in schools located near the e-waste site at Agbogbloshie. In addition, it was intended to determine the body burden of metals such as lead, manganese, cadmium, chromium and nickel in blood and urine of pupils recruited for the study. The findings from the study would guide policy makers in urban areas relating to siting of schools in order to avoid exposure to pollutants with adverse effect on pupils' cognitive function.

1.2 Problem Statement

In Ghana e-waste imports keep increasing and as a result have lead to the expansion of e-waste processing activities in the Agbogbloshie area. Agbogbloshie is surrounded by a large community, industries, and schools. Heavy metals released from the e-waste burning during recycling pollute neighboring communities and schools. Each year, it is estimated that about three million children die due to environment-related diseases [World Health Organization (WHO), 2012]. Analysis of soil samples taken from the community was noted to contain levels as high as 18 125 ppm of lead (Cannavaro et al., 2011). Children living and or attending schools located close to the Agbogbloshie e-waste recycling site may be exposed to toxic fumes. Lead exposure in urban and rural schools in Ghana is known and has been linked to leaded gasoline (Ankrah et al., 1998), but did not find the effects of exposure on the IQ of school children. However, they concluded that factors other than leaded gasoline may be important determinants in exposure to lead.

The hazardous inorganic metals such as Pb, Mn, Cd, Cr, and Ni found in e-waste have strong neurodevelopment and neurobehavioral effects on cognition especially in children (Hornung et al., 2009). E-waste exposure in Agbogbloshie represents a situation of continuous exposure, which raises concerns about neurodevelopment deficits in young children attending schools around e-waste sites. Although many studies have associated informal e-waste recycling to several adverse cognitive health outcomes such as low intelligence quotient, poor memory, attention deficit, learning disability in studies elsewhere **(**Chen et al., 2011), no such studies have enumerated such effects of e-waste on school pupils IQ in Ghana. This necessitated the assessment of the body burden of heavy metals concentrations of Pb, Mn, Cd, Cr and Ni and to ascertain the association of these metals with cognitive function of JHS 1 pupils.

1.3 Conceptual Framework

In the flow chart illustrated in **Figure 2**, e-waste generated within the country or imported undergoes testing and sorting (**Box 2**) after which devices which pass the testing and sorting are sold. Unsellable devices are dismantled and size reduced (**Box 3**). Vital parts are retrieved but non vital parts are discarded after the separation of materials (**Box 4**). The vital parts comprising of insulated wires and transistor components retrieved are processed by open burning (**Box 5**). This is done to remove the coatings and insulations. The open burning process releases toxic gases into the ambient environment (**Box 6**) which are transported in the environment affecting pupils. Individuals such as school children accumulate neurotoxicants in their body by mostly inhalation (**Box 7**) and build up doses in their body organs such as the brain and blood. This may cause neural cell proliferation, myelination, differentiation and synaptic formation (**Box 8**) which alters brain structure (**Box 9**) leading to adverse health outcomes of the brain causing low IQ,

poor memory, poor concentration, difficulty in decision making, slurred speech, learning disability and inattentiveness (**Box 10**).

CONCEPTUAL FRAMEWORK

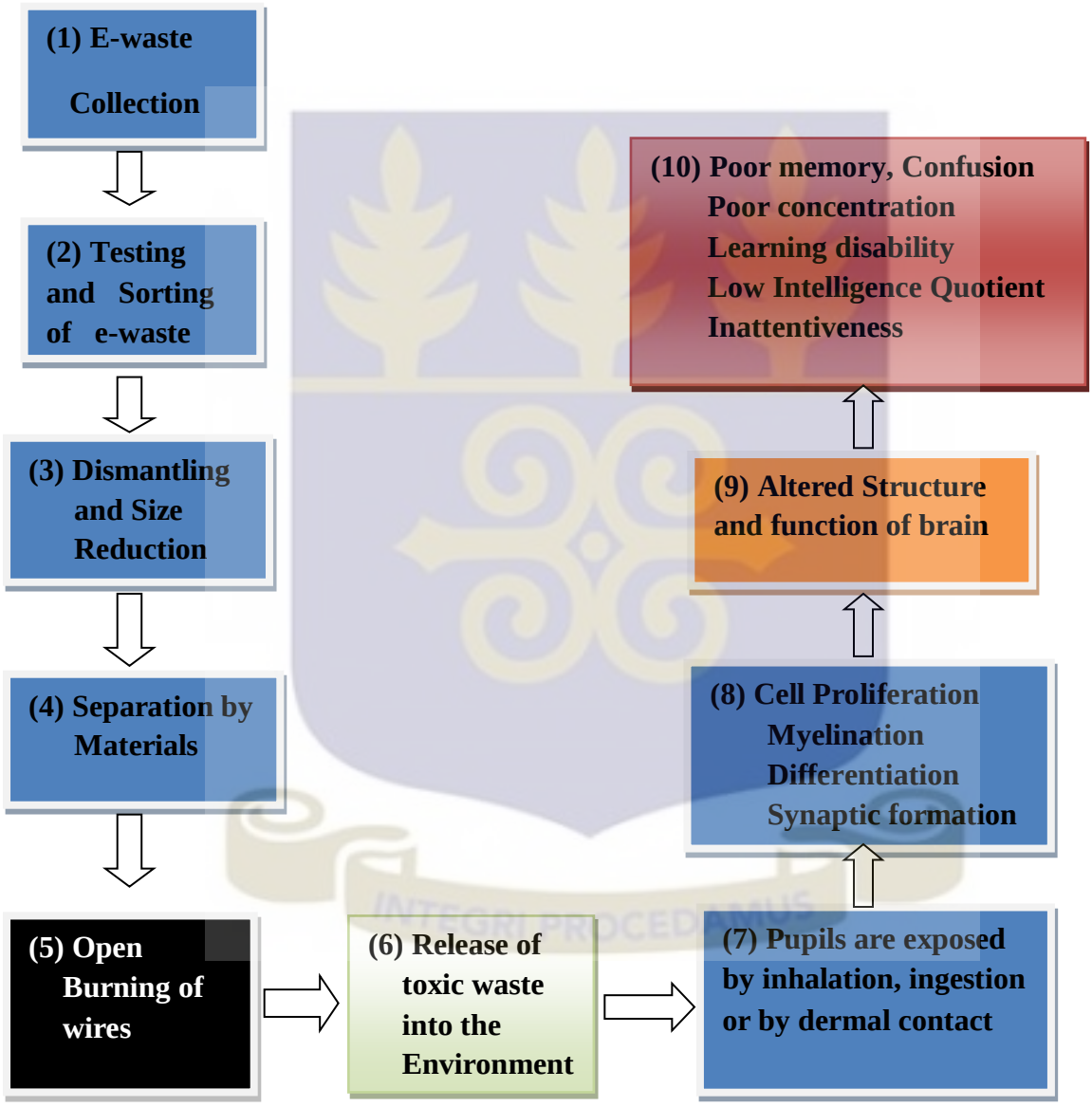

Figure 2- A flow chart showing how e-waste activity impact on cognitive function.

1.4 Justification

Currently, there are a number of international initiatives that are addressing global e-waste management and trade concerns as well as issues with environmental pollution due to e-waste recycling (WHO, 2012). E-waste and child health initiative is aimed at protecting children and their families from the detrimental health consequences caused by e-waste exposure. Initial support is being provided by the United States Environmental Protection Agency, United States National Institute of Environmental Health Sciences and the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety. Agbogbloshie remains an environmental threat and is reported to be inhabited by over 40 000 people and like many other poor neighborhoods in Ghana, the fertility rate is high (Ghana Demographic Survey, 2010; Feldt et al., 2013). Community schools at Agbogbloshie are within 1 km of the e-waste processing site (see **Section 3.2, Figure 4**). Considering the proximity of the schools from the waste site, it is expected that pupils in these schools may be exposed to mixtures of pollutants from the e-waste activities (Dogbevi, 2011; Monbiot, 2011). Low IQ, poor memory, poor concentration, confusion, learning disability and inattentiveness have been associated with poor outcomes in later life such as poverty, low self esteem, and increased divorce rate (Ashong, 2001; Nkyi, 2015). Children are especially the most vulnerable group to the health effects of exposure and need more protection. It is therefore important to understand the effects of heavy metals on cognitive function so that appropriate intervention programs are designed to reduce adverse outcomes in this disadvantaged community. This is because they are the future generation of children who would drive the economic growth and development of the nation. It is therefore important to conduct this proposed study to assess the extent of exposure to provide evidence

that would inform decision to be deployed to safeguard our future leaders from further damaging effects of exposures from e-waste activities on school children around Agbogbloshie.

1.5 Study Objectives

1.5.1 General Objective

The general objective of the study was to assess the body burden of blood (Pb, Mn), urine (Cd, Cr and Ni) and cognitive functions of JHS 1 pupils in schools around the e-waste processing site at Agbogbloshie.

1.5.2 Specific Objectives

The specific objectives of the research was to determine the;

i. prevalence of cognitive well-being among pupils.

ii. mean concentration of heavy metal in blood (Pb,Mn) and urine (Cd, Cr,Ni) samples of pupils.

iii. association between mean BPb, BMn and UCd, UCr, UNi concentrations and Full- scale IQ.

CHAPTER TWO

LITERATURE REVIEW

2.1 Scope of Literature

The literature review focuses on definition of e-waste and intelligence quotient. Also, the health effects of e-waste are discussed. Several heavy metals have been identified at e-waste sites but in this review I will focus on Pb, Mn, Cd, Cr and Ni and their effects on cognitive function of pupils.

2.2 Definition of E-waste

E-waste may be defined as discarded end of life computers, office electronic equipment, entertainment electronic devices, mobile phones, television sets and refrigerators which depend on electrical currents or electromagnetic fields in order to work properly and comprising of toxic metallic (inorganic) and plastic (organic) components. It could be divided into 3 main categories: (i) large household appliances such as refrigerators and washing machines, (ii) information technology (IT) and telecom gadgets such as personal computers, monitors and laptops and (iii) consumer equipment such as Televisions, Digital Video Display (DVD) players, mobile phones, Motion Picture- layer 3 (MP3) players, leisure and sporting equipment (Heart and Agamuthu, 2012).

2.3 Intelligence Quotient

A test of intelligence which is used to obtain an individual's 'intelligence quotient', or IQ, is an estimate of their relative cognitive abilities. Intelligence quotient is a prominent aspect of psychological testing over a century and one of psychology's greatest achievements. Critics

complain that no single test can capture the complexity of human intelligence and all measurements are imperfect. Furthermore, no single measure is completely free from cultural bias and there is the potential for misuse of scores on tests of intelligence. However, IQ has utilitarian value because it is a reasonably good predictor of grades at school, performance at work, and many other aspects of success in life (Gottfredson, 2004). Students who score high on tests such as the Scholastic Aptitude Test (SAT) and the American College Test (ACT), obtain scores which correlate highly with IQ measures (Detterman and Daniel, 1989), and tend to perform better in school than those who score lower (Coyle and Pillow, 2008). Similarly, people in professional careers, such as attorneys, accountants, and physicians, tend to have high IQs. To this day, IQ tests are used very widely for purposes of educational and occupational prognosis, and for clinical diagnosis, as well as psychological research and theorizing. Coupled with claims that differences in scores reflect innate differences in cognitive ability, IQ testing has formed the basis for assessing cognitive functions (Richardson, 2000).

> *"Intelligence refers to an individual's capacity to (i) acquire knowledge to learn and to understand, (ii) apply knowledge to solve problems and, (iii) engage in philosophical thinking. It is the power of an individual's intellect, and as a result a very important aspect of an individual's overall health."* (Boeree, 2003)

Intelligence Quotient (IQ) is the score you get on an intelligence test. Originally, it was a quotient of the mental age (MA) and the chronological age (CA): IQ= MA/CA x 100. Currently, scores are calibrated against norms of actual population scores. IQ tests are standardized after testing many thousands of people and an average IQ set at 100 established as a score above or below this norm is being used to establish the subject's actual IQ rating.

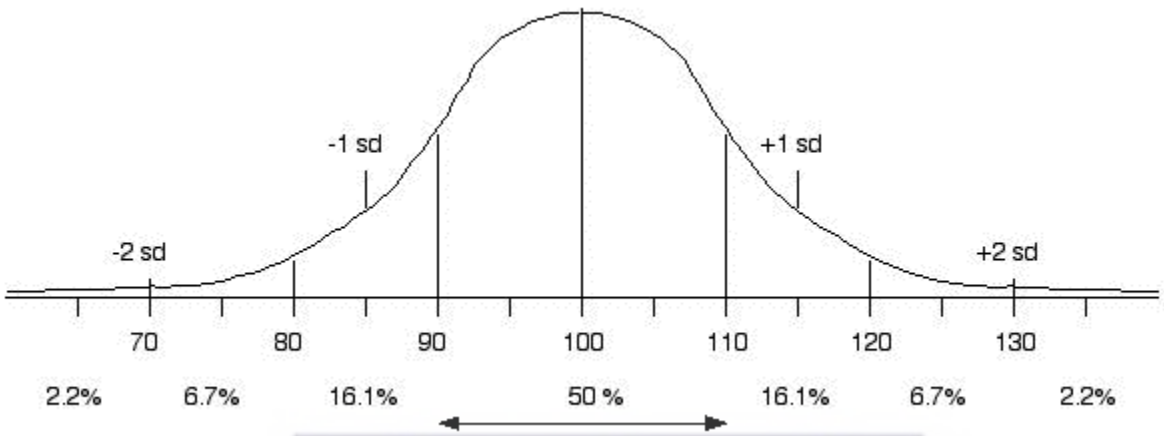

Figure 3- Normal distribution of IQ in human populations.

Source: Boeree, 2003.

There are several different types of intelligence tests. These include Cattell, Stanford-Binet, Raven and Wechsler among others and each has its own different scale of intelligence. The Stanford-Binet is heavily weighted with questions involving verbal abilities, and the Wechsler scales consist of two separate verbal and performance sub-scales, each with its own IQ rating. The Wechsler scale (Wechsler, 1954) which is used in this study classifies intelligence levels normalized to human populations as follows;

- Under 70 [mentally retarded] -- 2.2%
- 70-80 [borderline retarded] -- 6.7%
- 80-90 [low average] -- 16.1%
- 90-110 [average] -- 50%
- 110-120 [high average] -- 16.1%
- 120-130 [superior] -- 6.7%
- Over 130 [very superior/Genius] -- 2.2%

It is certainly true that some groups have higher or lower average intelligence than others, whether through environmental or genetic causes. The biggest difficulty for society and individuals regarding intelligence is retardation because beyond the age of 18, little or no improvement in a person's IQ rating is found. The method of calculating the IQ of a child differs from the method used for an adult. The Wechsler Intelligence Scale for Children-Fourth edition (WISC-IV) takes care of this (see **Appendix 3**). It is a standardized individually administered intelligence test for children between the ages of 6 to 16 inclusive that can be completed to generate IQ scores which represent a child's cognitive ability.

When measuring the IQ of a child, the subject will attempt an IQ test which has been standardized with an average score recorded for each age group. Thus, a child aged 10 years who scored the results expected of a child of 12 years would have an IQ of 120.

Unlike high intelligence, low intelligence is further classified into several sub-categories:

- 0 - 20 (profound) -- needs nursing care
- 20 - 35 (severe) -- can learn to talk and develop health habits
- 35 - 50 (moderate) -- second grade, needs sheltered care
- 50 - 70 (mild) -- educable to the sixth grade, minimally self-supporting

As a result low intelligence has significant social effects and cognitive well-being is essential for an individual's success in life.

2.4 Health Effects of E-waste

Several toxicants have been identified in e-waste and these include but not limited to lead, manganese, cadmium, chromium, nickel, Polyvinyl chloride (PVC), Brominated flame retardants

(BFRs) and chromium which are integral part of components of Electrical and Electronic Equipment (Heart and Agamuthu, 2012) and a television set or computer monitor contain significant amounts of lead, cadmium, barium, phosphorus and so on (Liu et al., 2009). These chemicals or substances when released into the environment may have dire consequences on humans and other living organisms (Wu et al., 2010). Adverse health effects of e-waste have been reviewed recently and it was concluded that e-waste may have detrimental effects on lung function, thyroid function, hormone expression, birth outcomes, childhood growth, mental health and cognitive development (Grant et. al., 2013). Cytotoxicity and genotoxicity of e-waste has also been reported (Grant et al., 2013). It is also possible that exposure to hazardous chemicals produced by e-waste recycling may have carcinogenic effects and endocrine disruption properties that could lead to lifelong changes due to neurodevelopment anomalies and abnormal reproductive development (Chen et al., 2011).

Neurodevelopment deficits are a serious concern because children living in e-waste recycling communities may be exposed to high levels of toxicant mixtures throughout their life time. Also the body burden of e-waste metal toxins is higher in infants and children (Pronczuk de Garbino, 2004).

2.5 Heavy Metals Toxicity and the Environment

2.5.1 Lead

Lead occurs naturally deep in the earth crust in small amounts. Although lead occurs naturally in the environment, anthropogenic activities such as fossil fuels burning, mining, and manufacturing contribute to the release of high concentrations. Lead is found in paint, household interior decorations, leaded gasoline, in electronic components and contaminated food. Exposure to lead can occur from living in buildings with interior painting containing lead, eating

contaminated food, inhaling fumes from vehicles using leaded gasoline or from open burning of electronic components. (Zheng et al., 2012). Ha et al., (2009) observed high mean levels of lead in the blood of children 1-6 years living in an e- waste site to be 50% higher compared to children from control sites. Knowledge about the threat posed by lead exposure to children's learning and development dates back at least to 1904 when J. Lockhart Gibson documented the harm suffered by children who chewed on the painted walls and verandas of houses (Gibson, 1904). Although it was believed originally that lead levels of 40-80 µg/dl were required to result in adverse impacts on children's health, studies have suggested that blood lead levels (BLL) below 10 µg/dL is associated with decrements in childhood intellectual quotient (Canfield et al., 2003; Jusko et al., 2008; Liu et al., 2013). However, the U.S. Center for Disease Control (CDC) has proposed that blood Pb level (BLL) above 10 µg/dL should be detrimental to cognitive functions of children, suggesting that among researchers there is no consensus on the threshold level for lead among children (CDC, 1991). However, it is now becoming increasingly evident from recent studies that decline in intellectual ability is observed at BLLs below 10 µg/dL (Canfield et al., 2003; Hu et al., 2006; Jusko et al., 2008; Kordas et al., 2006; Lanphear et al., 2005; Pocock et al., 1994; Schnaas et al., 2006; Schwartz 1994 and Tellez-Rojo et al., 2006). Canfield has shown that a 10 µg/dL increase in blood Pb level result in 4.6 intelligence quotient (IQ) point decrease (Canfield et al., 2003) while increases in the blood Pb level from 1 µg/dL to 10 µg/dL resulted in decreases of 6.2–7.4 IQ points (Canfield et al., 2003 and Lanphear et al., 2005). Some authors even suggest that there may be no threshold for the negative health effects of Pb, especially concerning the IQ of children (Bellinger, 2008; Landrigan, 2000; Mobidity and Mortality Weekly Report (MMWR), 2004). Children with lead exposure manifest inattention and hyperactivity symptoms and show increased risk for conduct problems, mood swings, and

learning disabilities, (Costello et al., 2003) which can result in significant medical and educational expenses (Leibson et al., 2001).

2.5.2 Manganese

There are numerous sources of manganese that contribute to global manganese pollution although manganese constitutes a small portion of the earth crust (ATSDR, 2008). Some of these sources include; (i) drinking water, either from deep wells or flowing water bodies (ii) mining activities (iii) battery manufacturing or recycling of old batteries (iv) vehicular exhaust fumes and (v) charcoal industry (Mielke et al., 2000). Most human exposure to manganese occurs through drinking water or occupational exposure (WHO, 2004). In recent times manganese may also be released from e-waste during recycling processes to retrieve poisonous metals of economic value.

Manganese is known to be a health hazard to workers at high doses but its effects at low doses are not properly understood (ATSDR, 2008). There are three major targets for toxicity: the brain, the lungs, and the testes. High doses of manganese cause severe neurological degenerative condition known as Manganism.

There is growing interest in environmental manganese exposure in children. Recent studies have suggested that excess Mn may interfere with developing brain functions. In Bangladeshi children, Wasserman et al., (2006) observed a negative effect of high Mn levels in tube well water on cognitive capacities. Bouchard et al., (2007) reported a significant association between hair manganese (MnH) levels and hyperactive and oppositional behaviour in children exposed to Mn through municipal well water in Quebec. Decrements in IQ scores in Korean children were associated with elevated blood Mn levels in a cross sectional population- based study but Mn

sources were not identified (Kim et al., 2009). Zoni et al., (2007), in a review of recent studies on neurobehavioral performance and manganese exposure across the lifespan, suggested that children's cognitive functions might be particularly vulnerable to manganese. The developing nervous system is a prime target for the disrupting effects of toxic chemicals (Landrigan et al., 2005; Rice and Barone, 2000; Bellinger, 2009). In a birth cohort study in France, cord blood Mn was negatively associated with attention and non-verbal memory and boys' manual ability at 3 years, after adjusting for mother's educational level. (Takser et al., 2003).

2.5.3 Cadmium

The first effect on human health related to Cd exposure, was the damage to the lungs of Cd-exposed workers, published in 1938 (Nordberg, 2004). Some years later, pathological bone fractures and severe pain named Itai-Itai disease occurred after World War II, in Toyama Japan, as a consequence of Cd exposure (Nordberg, 2004). Cadmium continues to remain an important industrial metal. It is extracted during the production of other metals, such as zinc, lead and copper and it is used in industrial and household products, mainly in batteries, pigments, metal coatings, plastics and some metal alloys (ATSDR, 2008). In spite of the fact that Cd is a widespread industrial and environmental pollutant, it is present in low amounts in food, and dietary intake and also in e-waste (Wang and Yanli, 2013). It is also present in cigarette smoke representing a significant source of exposure (Saldivar et al., 1991; Stohs et al., 1997). The major source of exposure is by inhalation [Office of Environmental Health Hazard Assessment (OEHHA), 1999]. Cd has been shown to cause severe damage to a variety of organs, including the brain and lungs (Wang and Yanli, 2013). Exposure to high dose may cause death (Wang and Yanli, 2013).

2.5.4 Chromium

Environmental sources of chromium include cement dust, tobacco smoke and wearing of asbestos lining (ATSDR, 2008). Chromium is used in alloys and therefore found in electronic devices [Occupational Safety and Health Administration (OSHA), 2009]. Chromium is also found in paint, batteries, candle, dye, toner, cement and rubber products (ATSDR, 2008). Exposure normally occurs through ingestion of contaminated food, dermal contact and inhalation (ATSDR, 2008). The health effects associated with chromium includes but not limited to cancer and neurological disorders (U.S. EPA, 2008) Inhalation of chromium, in particular hexavalent chromium (Cr VI), can cause human lung cancer (Brandt-Rauf, 2006). A recent publication by Beaumont et al., (2008) concerning a study in the Liaoning Province in china documents increased cancer risks following ingestion of Cr VI in drinking water. In particular increased stomach cancer risks were manifested, but some evidence also indicated increased lung cancer risks. Zheng et al., (2013) examined the association between lung function and three transitional metals (Cr, Ni, Mn) in school children living in an e-waste recycling area and observed significantly higher levels of Ni and Mn among boys living close to the e-waste site. They concluded that accumulation of blood Mn, serum Ni may be risk factors for oxidative damage. With respect to cognitive function not much is known about the effect of chromium (ATSDR, 2008).

2.5.5 Nickel

Nickel occurs naturally in the earth's crust and natural exposure may occur through volcanic eruptions and wind blowouts. Nickel is widely used in the electronic industry and is a component of semiconductor devices (ATSDR, 2008). Nickel is found in components of electronic devices and is released during open burning (ATSDR, 2008). Nickel load in the body has being known to

cause effects in the brain particularly nerve damage (Das et al., 2008). Anthropogenic exposure occurs through industrial activities such as nickel mining, smelting, waste incineration and Cadmium-nickel battery manufacturing (ATSDR, 2008).

Occupational exposure to nickel may occur by inhalation or dermal contact of aerosols, dusts, fumes or mists containing nickel (Angerer & Lehnert 1990). Dermal contact may also occur with nickel solutions, such as those used in electroplating, nickel salts, and nickel metal or alloys. Also, nickel-containing dust may also be ingested in the face of poor work practices or poor personal hygiene (Angerer & Lehnert 1990). Water soluble nickel compounds have greater affinity for the brain and more is dissolved into the blood stream through the lungs and excreted mainly through the kidneys (Angerer and Lehnert 1990).

Common health effects of nickel exposure include allergic reactions such as skin rashes at the site of contact (ATSDR, 2008). Various studies have reported neurologic sequelae of acute and chronic Nickel exposure in adults and children (Das et al., 2008). Neurotoxicological impairment caused by nickel includes poor cognitive performance and disturbances in visual perception, psychomotor speed, attention, speech and memory (Das et al., 2008). Other harmful health effects from exposure to nickel include chronic bronchitis, reduced lung function, and cancer of the lung and nasal sinus.

In summary, Pb, Mn, Cd, and Ni have been associated with several diseases including reduced IQ, but with respect to Cr nothing has been reported.

CHAPTER THREE
METHODS

3.1 Study Design

A cross-sectional study was conducted over a period of two months from May to June 2015 among JHS 1 pupils in schools around the e-waste site at Agbogbloshie.

3.2 Study Area

Agbogbloshie e-waste site is among the top ten most polluted places in the world (Blacksmith Institute, 2013). The site covers about 15 acres of land and is located west to the Odaw river where cluster of schools and many businesses such as banks, pharmaceutical companies, breweries, shops, various manufacturing companies, and many self-employed and petty traders operate on a daily basis. Located east to the e-waste site is a large residential community about 100 meters across the Odaw river that primarily houses Agbogbloshie workers and their families. This densely populated community consists of small informal wooden settlements with little or no basic amenities such as electricity, treated water, toilets and bathing facilities. The study was conducted in four (4) schools, namely Ayalolo 1&2 JHS, Amamomo JHS, Ashia Mills JHS and Richard Akwei Memorial School, located approximately 1km from the e-waste burning site (see **Figure 4**).

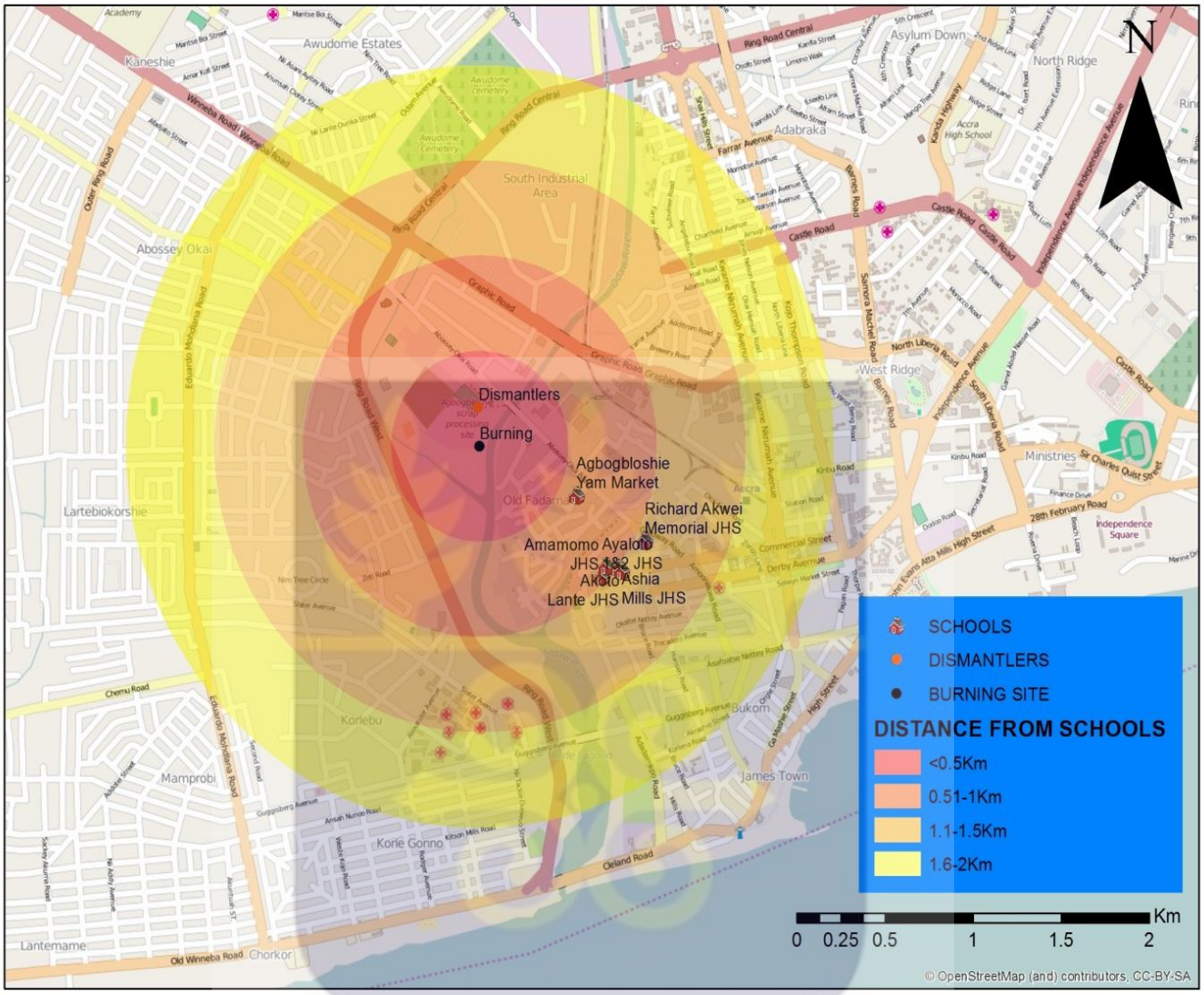

Figure 4- Map showing Agbogbloshie e-waste site and study schools.

Source: Adapted from Google maps 2015.

3.3 Variables

3.3.1 Dependent Variables

The dependent variables in the study were intelligence quotient (IQ) and cognitive well-being defined as poor memory, confusion, poor concentration, difficulty in making decision, stuttering/stammering, slurred speech, learning disability and inattentiveness.

3.3.2 Independent Variables

The independent variables were concentrations of blood lead (B-Pb), blood manganese (B-Mn), urine cadmium (U-Cd), urine chromium (U-Cr) and urine (U-Ni).

3.3.3 Confounders

The confounders were maternal education level and parental smoking. These confounders are known risk factors for IQ in children (Yeates et al., 1983; Walfisch et al., 2013).

3.3.4 Source/Study population

The source population included all JHS 1 pupils attending schools located around the e-waste site at Agbogbloshie (**Figure 4**). From this population, 50 pupils were randomly selected to voluntarily provide blood and urine samples for chemical analysis.

3.4 Inclusion and Exclusion criteria

A pupil was included in the study if (i) s/he was willing to follow the study protocol and (ii) a biological parent or guardian was willing to take part in the questionnaire.

Pupils in other classes and those with mental health problems, confirmed by a parent or a teacher were excluded.

3.5 Data collection tools

The data collection tools included a questionnaire, blood and urine sampling kit (vacutainers), a weighing scale and a stadiometer for standing height measurement.

3.5.1 Questionnaire

Questions on cognitive well-being and IQ were adapted from the toxicity questionnaire and American version of child IQ test was used in this study. The questionnaire was divided into five (5) sections. Section 1 was used to collect information on the socio-demographic characteristics of pupils such as sex, age, weight, height, marital status of a parent/guardian and level of parent/guardian education. Section 2 focused on exposure in the school environment such as exposure to dust, smoke from cigarette, smoke from the burning of e-waste and type of material used in ceiling and walls in the classroom. Section 3 dealt with exposure occurring in the home environment such as proximity to busy road, exposure to dust, smoke from cigarette, smoke from the burning of e-waste and type of material used in ceiling and walls in the room. Section 4 dealt with cognitive well-being and this included questions on poor memory, confusion, poor concentration, difficulty making decision, learning disability and inattentiveness. The fifth section was an American version of child IQ test for ages 6 to 16 years using the Wechsler Intelligence Scale for Children-Fourth Edition which was used to measure Full-Scale IQ (**Appendix 4**).

3.5.2 Blood sample collection

A qualified phlebotomist was employed to collect blood samples. Triplicate samples of whole blood haematology tubes two free and one containing Z-gel, an additive carrier and a clot activator (for serum separation) capable of storage at -20 °C were used for the blood sample collection. Butterfly needles (Sarstedt, S-monovette, Germany) were used for venipuncture and a tourniquet to improve vein visibility. 7.5 mL of whole blood was collected from the median cubital and cephalic veins into three separate haematology tubes, labeled and stored in cold boxes at 4-8 °C for onward transportation to Germany for further storage at -20 °C until analysis.

3.5.3 Urine sample collection

Urine sample collection was done by a qualified medical laboratory technician employed. The pupils were provided with clean water and soap for hand washing before handing out to them sterile metal-free plastic urine containers (Sarstedt S-monovette, Germany) for providing urine. They were instructed to void out the first portion of the urine stream before collecting 50 mL mid-stream urine into the plastic urine container supplied. Ten (10mL) each of the urine supplied by pupil was drawn into three separate sterile urinary tubes with an in-built plunger (Sarstedt S-monovette, Germany) and labeled. Samples were stored in cold boxes for onward transportation to the Noguchi Laboratory for storage at 20 °C. Later, the samples were shipped to the Analytik Jena Institute of Occupational and Social Medicine Laboratory RWTH University, Aachen, Germany for analysis for heavy metals in blood and urine.

3.6 Laboratory analysis of heavy metals

Blood and urine samples were analyzed using High Resolution Continuum Source Atomic Absorption Spectrophotometry (H-RCS AAS) ContrAA700, Analytik Jena Institute of

Occupational and Social Medicine Laboratory RWTH University, Aachen, Germany for blood lead, blood Manganese, urine cadmium, urine chromium and urine nickel according to methods of Deutsche Forschungsgemeinschaft (DFG), European chemical Industry Council (Angerer, 1982; Fleischer, 1988).

Blood samples were analyzed by diluting 0.1 mL blood in 1.8 mL matrix modifier reagent (composed of Triton X-100 and ammonium hydrogen phosphate dibasic for blood Pb analysis and ammonium hydrogen phosphate monobasic for blood Mn analysis), and then each were mixed well using the vortex mixer and assayed using High Resolution Continuum Source Atomic Absorption Spectrophotometry (H-RCS AAS) ContrAA700. The detection limit for blood Pb and blood Mn were 10 µg/L and 5 µg/L respectively because blood Pb and blood Mn levels were very high. Triplicate samples were analyzed. De-ionized water was used for washing, rinsing and dilution when needed. Apparatus washed were air dried before used in the laboratory. Urine samples were analyzed by mixing approximately 0.35 mL of urine samples per 100 mL with 65% HNO_3 to a pH of 2-3. The mixture was shaken to homogenize and warmed up to 50-60 °C. Samples are vortexed to dissolve sediment and assayed using High Resolution Continuum Source Atomic Absorption Spectrophotometry (H-RCS AAS). The detection limit for urine Cd, Ni and Cr were 0.2 µg/L, 0.2 µg/L and 0.2 µg/L respectively.

3.7 Quality Control

The following measures were undertaken so as to ensure that the data collected were of high quality. The IQ test was administered to the pupils individually in a serene environment at the Richard Akwei Memorial School library by a qualified educational psychologist. Research assistants were trained in questionnaire administration. A qualified phlebotomist and a laboratory

technician were employed to collect blood and urine samples respectively. Sterilized sample containers were used for urine sample collection. Participants washed their hands with soap and water before urine sampling. Mid-stream urine samples of pupils were collected early in the morning. Urine samples were packed in cool boxes containing ice packs to maintain the integrity of samples sent to laboratory for analysis.

For laboratory analysis of heavy metals, triplicate analysis of blood and urine samples were carried out with outmost precision.

Internal control measures of the Analytik Jena Institute of Occupational and Social Medicine Laboratory RWTH University, Aachen, Germany were used to ensure validity of the analysis conducted. This involved a continuous critical evaluation of the laboratory's own methods and working routines. A control chart was used to run control samples together with the routine samples. Data were recorded in such a way that trends were detectable.

External control measures of the laboratory ensured that results of biological samples analyzed were compared with threshold limit values and results of parallel samples sent to the laboratory of the German Society for Occupational and Environmental Medicine.

3.8 Data collection

The mothers/female guardians of all the pupils and the authorities of the index schools were fully informed about the purpose of the study and were provided written consent with sampling collection dates. Mother/female guardian and child were interviewed after which blood and urine samples were collected. Questions on the American version of child IQ were then administered to the pupils in a quiet room. The IQ test lasted for 45 minutes.

3.9 Data processing and Statistical analysis

Data entry was done using Epi- Info 7 (Centre for Disease Control, CDC, USA) by coding the items in the questionnaire and entered by two separate assistants after which excel sheets were produced and compared. The data was exported into STATA version13 (Stata Corp., College Station) for analysis. Data was checked for normality and outliers using the Q-Q and box plots respectively. Due to small data size, responses 0 to 2 of (see **Section 4**) of questionnaire on cognitive well-being were collapsed into "NO" and responses 3 and 4 were collapsed into "YES". The prevalence of cognitive well-being was computed to compare proportions. Means and standard deviations of the heavy metals concentration and IQ were calculated. Multiple regression analyses were used for the association between heavy metals in urine and blood and IQ controlling for maternal educational level and parental smoking.

3.10 Ethical Consideration

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki [Journal of the American Medical Association (JAMA), 2013]. Ethical clearance was obtained from the ethics committee of the Ghana Health Service (see **Appendix 1**). Permission to conduct research was also sought from the Director of Education in-charge of the Greater Accra Metropolis, school heads and class teachers from the four schools where pupils were recruited for the study. Written consent of pupils aged 11 to 16 years and their parents was also sought and both pupil and parents endorsed individually designed consent forms voluntarily before they were allowed to participate. For anonymity, data analysis was done as aggregate summaries.

CHAPTER FOUR
RESULTS

4.1 Demographic Characteristics of the Pupils Studied

Socio-demographic characteristics of the pupils are shown in **Table 1** below. Of the twenty-one (21) pupils, 47.6% were males whilst 52.4% were females. Their mean age was 12 (±0.19) years. The mean weight was 45.29 (±0.18) kg and the mean height was 19.27 (±0.56) cm. The pupils have either spent 1-5 years (61.9%) or 6-10 years (38.1%) in the current school. The mothers/guardians were mostly educated to the senior high school level (66.6%) and married (42.9%). Most of the students spent about 2-3 cedis a day at school (80.9%).

Table 1: Socio-demographic characteristics of pupils in the study Schools.

Characterristics	**Frequency (n=21)**	**Percentage (%)**	**Mean(±SD)**
Sex			
Male	10	47.6	
Female	11	52.4	
Age (years)			12.0(0.88)
Weight (kg)			29.6(0.19)
Height (cm)			19.3(0.56)
Years in present school compound			
1-5 years	13	61.9	
6-10 years	8	38.1	
Mothers Highest Education			
Middle School/Junior High School	4	19.1	
Senior High School	14	66.6	
*[1]Others	3	14.3	
Marital status of parents			
Married	9	42.9	
*[2] Others	12	57.1	
Amount of money spent daily at school			
0-1 cedi	3	14.3	
2 cedis and above	18	85.7	

SD= Standard Deviation, JHS= Junior High School

*[1] Other= Professional Institute, Tertiary Institution

*[2] Other= Divorced, Separated, Widowed, Single, Never married

The pupils were mostly represented by Ashia Mills JHS (38.1%), Richard Akwei Memorial JHS (38.1%) and least represented by Ayalolo 1& 2 JHS (**Figure 5**).

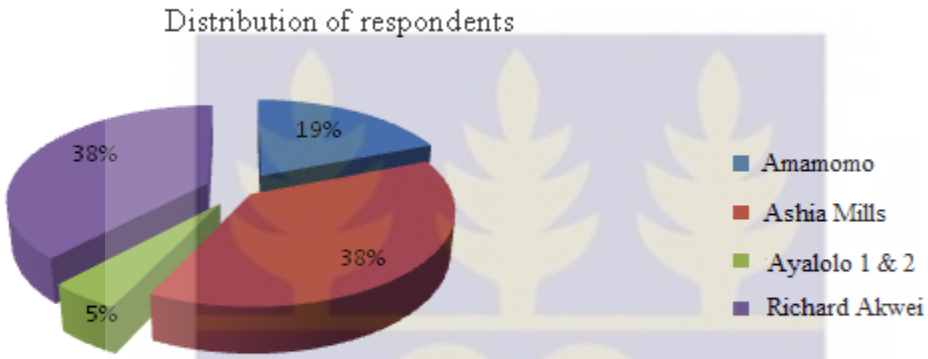

Figure 5- Distribution of pupils by School (n=21).

4.2 Prevalence of cognitive well-being

The prevalence of indicators of cognitive well-being is shown in **Table 2**. Inattentiveness (90.9%), difficulty making decisions (90.5%), confusion (71.4%) were the most prevalent challenges observed among the peoples. Stuttering/stammering (14.3%) and slurred speech (4.8%) were the least observed cognitive challenges.

Table 2: Prevalence of cognitive well-being. (n=21)

Cognitive well-being	Prevalence N(%)
Poor memory	
Yes	8(38.1)
No	13(61.9)
Confusion	
Yes	15(71.4)
No	6(28.6)
Poor concentration	
Yes	9(42.9)
No	12(57.1)
Difficulty making decision	
Yes	19(90.5)
No	2(9.5)
Stuttering/Stammering	
Yes	3(14.3)
No	18(85.7)
Slurred speech	
Yes	1(4.8)
No	20(95.2)
Learning disability	
Yes	11(52.4)
No	10(47.6)
Inattentiveness	
Yes	17(90.9)
No	4(9.1)

4.3 Concentration of heavy metals in blood and urine samples

The results were on twenty-one samples. The mean concentration of blood lead was the highest 63.36 (±28.37) µg/L followed by manganese in blood 11.55 (±4.76) µg/L then nickel in urine 5.47 (±1.34) µg/L. The rest of the results are shown in **Table 3 and 4.**

Table 3: Concentrations of Lead (Pb) and Manganese (Mn) in blood of pupils in µg/L. (n=21)

Heavy metal	Detection limit	Minimum	Maximum	Mean	SD
Pb	10.0	22.69	135.31	63.36	±28.37
Mn	5.0	5.67	22.48	11.55	± 4.76

SD- Standard Deviation

Table 4: Concentrations of Cadmium (Cd), Chromium (Cr) and Nickel (Ni) in urine of pupils in µg/L. (n=21)

Heavy metal	Detection limit	Minimum	Maximum	Mean	SD
Cd	0.2	0.02	1.45	0.32	± 0.04
Cr	0.2	0.03	1.10	0.37	± 0.03
Ni	0.2	0.77	17.70	5.47	± 1.34

SD- Standard Deviation

4.4 Intelligence Quotient Scores

A paper and pencil IQ test was administered individually to pupils. The test was scored and the Wechsler Intelligence Scale was used to determine a pupil's IQ score. The mean Full-Scale IQ score was 69 (±3.28) and scores ranged from 68 to 108. Of the twenty-one (21) pupils, (19) 90.4% scored Full-Scale IQ within the mean. This implies majority of the pupils had low IQ.

4.5 Association between Mean Heavy Metals Concentration and Full-Scale IQ

Table 5 presents the results from multivariate regression analysis. The crude estimate for lead shows a significant reduction in mean IQ β = 0.20, [95% CI 0.00, 0.40], p = 0.05. However, after adjusting for potential confounders a reduction in mean IQ was observed β = 0.56, [95% CI 0.20, 3.98], p = 0.123. The association was not significant. With respect to manganese, both

the crude β =-0.08, [95% CI -0.02, 1.05], p = 0.05 and adjusted β =-0.03, [95% CI -0.09, 2.98], p = 0.62 also did not have significant association with the IQ.

Table 4: Association between mean heavy metals concentration in µg/L and Full-Scale IQ. (n=21)

	Full-Scale IQ					
Heavy Metal	**Crude β**	**95% Confidence Interval**	**p-value**	***Adjusted β**	**95% Confidence Interval**	**p-value**
BPb	0.20	(0.00, 0.40)	0.05	0.56	(0.20, 3.98)	0.123
BMn	-0.08	(-0.02, 1.05)	0.89	-0.03	(-0.09, 2.98)	0.616
Ucd	3.67	(3.98, 17.33)	0.58	0.03	(0.04, 6.34)	0.929
Ucr	5.60	(4.74, 25.93)	0.57	-0.04	(-0.03, 9.54)	0.884
Uni	0.07	(0.05, 1.68)	0.93	0.06	(0.07, 3.56)	0.602

* Adjusted for Mother's education level and Parental smoking, β= regression co-efficient

CHAPTER FIVE

DISCUSSIONS

5.1 Summary of main findings

In the present study attention deficit, difficulty in making decision, confusion and learning disability were common among the pupils. The mean concentrations for blood lead blood manganese and urine nickel were high. The mean Full-scale IQ was 69. In a multivariate regression analysis, there was no statistically significant association between heavy metals studied and Full -Scale IQ.

5.2 Comparison of Results with Previous Findings

Chen et al, (2011) have associated informal e-waste recycling to several adverse cognitive health outcomes such as low intelligence quotient, poor memory, attention deficit, learning disability. In this study, attention deficit, difficulty making decision, confusion and learning disability were mostly noted among the pupils. However, there was not enough data for further analysis. The observed mean concentration of lead observed in the present study was 6 times higher than the threshold value 10 µg/dL. The present study demonstrated that levels of Pb in blood, Mn in blood, Cd in urine, Cr in urine and Ni in urine were not significantly association with the IQ in pupils. Other studies however, found significant association of these heavy metals on the IQ of children of school age (Bellinger, 2008; Canfield, 2003; Lanphear, 2005).

In studying pollutants, IQ is generally used to quantify the effects on neurological function. Although findings from several studies suggest how exposure to these toxic pollutants can result in neurological defects (Canfield et al., 2003; Hu et al., 2006; Jusko et al., 2008; Kordas et al.,

2006; Lanphear et al., 2005; Pocock et al., 1994; Schnaas et al., 2006; Schwartz 1994 and Tellez-Rojo et al., 2006), one major issue with these studies, however, is that it is often difficult to determine if exposure to the pollutants is the true cause of these defects as this current study results reveal. This is because exposure to the pollutants may have occurred after neurological effects were present from pregnancy. Or perhaps a known or unknown confounding variable may be responsible for the effects (Yeates et al., 1983, Walfisch et al., 2013). For example, parental level of education, smoking by mother during pregnancy or hunger from poverty factors may play a role in poor child development pre-term. Another issue is that the people in the study may have differing levels of exposure, making it difficult to quantify a potential dose-response relationship.

In vitro studies may only be able to fill in some of the gaps left by population studies. Using cell cultures, researchers may be able to deduce the mechanisms of action of toxins and pollutants on a cellular and biochemical level. Animal studies may potentially serve as the best way to study pollution's effects until more superior research methods are developed. In animal models, exposure can be quantified and assessed methodically. This is especially important for air pollution, which is particularly difficult to quantify exposure in human studies. Animal models may also serve as a way to model the mechanisms of action of pollutants on the nervous system as a whole, rather than just on a cellular level. Although many have studied the effects of smoking during the prenatal period, the effects of air pollution as a whole during this same time period are unknown.

5.3 Methodological validity

This is the first study among pupils in schools around the e-waste site on the relationship between heavy metals and IQ. Data on the exposure was collected objectively. The American versions of the IQ test and toxicity questionnaires were used to collect data on IQ and cognitive well-being respectively.

These questionnaires have been used extensively in different cultures and their reliability and validity have been reported. The data for analysis was subjective to the pupils' responses. This had the potential of bias as participant had to remember the number of years spent at the present school. In addition, this was a cross-sectional study, which limits interpretation of the results for a causal relationship. One major limitation of this study was the inadequate sample size. It precludes the possibility of finding an association if one exists.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Pollution is a significant and complex problem that affects infants, children and adults. This study revealed that pupils attending schools near the e-waste site have been exposed to heavy metals. The mean concentrations (SD) of heavy metals in blood and urine samples of the pupils were 63.3(28.3) µg/L, 11.55(4.7) µg/L, 0.32(0.04) µg/L, 5.47(1.3) µg/L, and 0.37(0.03) µg/L for Pb in blood, Mn in blood and Cd, Ni and Cr in urine respectively. Their mean IQ was below average according to Wechsler classification of IQ. Attention deficit, difficulty making decision, confusion and learning disability were also common among the pupils.

6.2 Recommendations

There is the need for a large longitudinal study to investigate the association between heavy metals and IQ among pupils in schools around the e-waste site at Agbogbloshie. E-waste recycling activities should be formalized with improved recycling methods to reduce environmental pollution. Future urban planning should be of concern to avoid the Agbogbloshie e-waste recycling scenario. As a matter of urgency government should consider relocating the e-waste site from the present location. Alternative methods that would prevent dispersion of smoke into the environment should be sought and applied to save the environment and human lives. Government should create and enforce legislation to promote the safe use and disposal of e-waste, promote policies to reduce and remedy pollution caused by e-waste recycling. Avoid the construction of homes, schools and playgrounds near polluted areas and hazardous installations.

All children of school age within the Agbogbloshie area should be assessed for developmental and behaviour status and seek further evaluation and therapy to reduce developmental or behavioural problems. It is important that bio-monitoring program should be initiated in which public health practitioners should consider the potential influences of heavy metals. Also conducting developmental screening for children with multiple developmental risk factors which might include heavy metal exposures should be a matter of priority by instituting frequent developmental surveillance or by conducting more extensive developmental evaluations.

A popular technique in assessing the neurological effects of pollutants is the use of global measures such as IQ, which is useful for determining cut offs and acceptable levels of exposure. The use of specific scales and outcome measures in future studies may be more useful clinically. Another potential area of study in the future is comparing the effects of pollutants in prenatal versus postnatal time periods. Differing routes of exposures as well as different developmental stages may lead to different effects. Multidisciplinary research in the fields of biology, chemistry, ecology, neurology, and more can address gaps in the science and better identify the mechanisms and potential effects of different pollutants on the brain while potentially shaping public health policy, contributing to legislation and regulation, and stimulating research and the development of environmental technologies that minimizes pollution from heavy metals.

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APPENDICES

APPENDIX 1- ETHICAL CLEARANCE

GHANA HEALTH SERVICE ETHICS REVIEW COMMITTEE

In case of reply the number and date of this Letter should be quoted.

My Ref. :GHS-ERC: 3
Your Ref. No.

Research & Development Division
Ghana Health Service
P. O. Box MB 190
Accra
Tel: +233-302-681109
Fax + 233-302-685424
Email: Hannah. Frimpong@ghsmail.org

8th June, 2015

Agbeko Mawutor Kwame
School of Public Health
University of Ghana
Legon, Accra

ETHICS APPROVAL - ID NO: GHS-ERC: 83/02/15

The Ghana Health Service Ethics Review Committee has reviewed and given approval for the implementation of your Study Protocol titled:

"Effect of E-Waste on Cognitive Functions of JHS 1 Pupils in Schools around E-waste Site at Agbogbloshie"

This approval requires that you inform the Ethics Review Committee (ERC) when the study begins and provide Mid-term reports of the study to the Ethics Review Committee (ERC) for continuous review. The ERC may observe or cause to be observed procedures and records of the study during and after implementation.

Please note that any modification without ERC approval is rendered invalid.

You are also required to report all serious adverse events related to this study to the ERC within seven days verbally and fourteen days in writing.

You are requested to submit a final report on the study to assure the ERC that the project was implemented as per approved protocol. You are also to inform the ERC and your sponsor before any publication of the research findings.

Please note that this approval is given for a period of 12 months, beginning June 8th 2015 to 7th June 2016.

However, you are required to request for renewal of your study if it lasts for more than 12 months.

Please always quote the protocol identification number in all future correspondence in relation to this approved protocol

SIGNED.....
DR. CYNTHIA BANNERMAN
(GHS-ERC CHAIRPERSON)

Cc: The Director, Research & Development Division, Ghana Health Service, Accra

1

APPENDIX 2- PARTICIPATION INFORMATION AND INFORMED CONSENT

Institutional Affiliation

Department of Biological Environmental and Occupational Health Sciences (BEOHS): School of Public Health, College of Health Sciences, University of Ghana-Legon.

Background

Dear participant, my name is Mawutor Kwame Agbeko. I am a student of the school of Public Health, University of Ghana. I am conducting a study on "Association between e-waste exposure and the effects on cognitive function of pupils attending schools around e-waste sites near Agbogbloshie". The purpose of the study is to assess the association of exposure of pupils to toxic metals from e-waste on cognitive function of pupils.

Procedures

The study will involve answering questions from a questionnaire developed for pupil and mother as well as taking an IQ test that will last for 45 minutes. There will also be 15-20 ml mid stream urine sampling from pupils who are willing to donate after signing consent forms. I will appreciate your participation in this study. This is purely an academic research which forms part of my work for the award of a master's degree.

Risks and Benefits: Collection of urine samples non-invasive and will not cause any discomfort to participants. The results of the study will be used by policy makers to make policies that will protect children leaving in an environment polluted with heavy metals from e-waste processing. Every child who will participate will receive compensation of a tin of milo, a can of malt and two exercise books.

Right to refuse: Participation in this study is voluntary and you can choose not to answer any individual question or all the questions. You are at liberty to withdraw from the study at anytime. However, I will encourage you to participate since your responses are important in determining the outcome of the study to benefit society at large.

Anonymity and Confidentiality: I would like to assure you that whatever information you will provide will be handled with strict confidentiality and will be used purely for the research purpose. Your responses will not be shared with anybody who is not part of the research team. Statistical data analysis will be done at the aggregate level to ensure anonymity.

Dissemination of results

The result of this study will be mailed to you if you provide your address. Before taking the consent, do you have any question you wish to ask about the study? Yes ☐

No ☐ (if yes, questions to be noted below)

……

If you have questions later, you may contact the following people:

Mr. Mawutor Kwame Agbeko on 0202884010 or email me: *makwagbeko@yahoo.com*

Dr. Reginald Quansah on 0234404637 or email: *yaw121@yahoo.com* and

Prof. Julius Fobil on 0243462514 or email: *jfobil@ug.edu.gh*

Mrs. Hannah Frimpong on 0243235225 or 0507041223 GHS-ERC Administrator.

PARENT ASSENT FORM

I……., declare that the purpose of the study have been thoroughly explained to me as well as the involvement of my child to provide urine sample and to take an IQ test with my child. I hereby agree to answer the questions that will be asked in the study with my child and also allow my child to voluntarily respond to questionnaire items, donate urine and take an IQ test.

Signature of Parent……..…….. Date……

Mobile phone contact number: ……

If you have questions later, you may contact the following people:

Mr. Mawutor Kwame Agbeko on 0202884010 or email me: *makwagbeko@yahoo.com*. Student Invesigator

Dr. Reginald Quansah on 0234404637 or email: *yaw121@yahoo.com*. Supervisor

Prof. Julius Fobil on 0243462514 or email: *jfobil@ug.edu.gh*. Co-Supervisor

Mrs. Hannah Frimpong on 0243235225 or 0507041223. GHS-ERC Administrator.

CHILD/PUPIL ASSENT FORM

I……., declare that the purpose of the study have been thoroughly explained to me in the language I understand and I have understood. I hereby agree to answer the questions that will be asked in the study voluntarily in the questionnaire, donate urine and take an IQ test.

Signature/Thumb print of pupil ……. Date……

School Attending: ……

If you have questions later, you may contact the following people:

Mr. Mawutor Kwame Agbeko on 0202884010 or email me: *makwagbeko@yahoo.com*. Student Invesigator

Dr. Reginald Quansah on 0234404637 or email: *yaw121@yahoo.com*. Supervisor

Prof. Julius Fobil on 0243462514 or email: *jfobil@ug.edu.gh*. Co-Supervisor

Mrs. Hannah Frimpong on 0243235225 or 0507041223. GHS-ERC Administrator.

SCHOOL HEAD ASSENT FORM

I……., declare that the purpose of the study have been thoroughly explained to me and the pupils involved in this study in the language we understand and we have understood. I hereby agree that you use only pupils who upon parental consent have allowed their child to voluntarily participate by responding to questionnaire items, donate urine and take an IQ test.

Signature of School Head……..…….

Date……

Mobile phone contact number: ……

If you have questions later, you may contact the following people:

Mr. Mawutor Kwame Agbeko on 0202884010 or email me: *makwagbeko@yahoo.com*. Student Invesigator

Dr. Reginald Quansah on 0234404637 or email: *yaw121@yahoo.com*. Supervisor

Prof. Julius Fobil on 0243462514 or email: *jfobil@ug.edu.gh*. Co-Supervisor

Mrs. Hannah Frimpong on 0243235225 or 0507041223. GHS-ERC Administrator.

APPENDIX 3- QUESTIONNAIRES

Date: ___/05/2015

Participant Identification Number: | | | | |

Name of Pupil _____

Section 1: Personal Information and Socio-economic characteristics.

(Please shade the circles applicable to each participant and fill in the spaces).

1. Sex? **O** Male **O** Female
2. Age?:……(years)
3. Weight? .....kg
4. Height?.....m
5. Name of your school? **O** Amamomo **O** Ahia Mills
   O Ayalolo 1&2 **O** Richard Akwei
6. For how many years now have you being attending school on this compound? **.....** years
7. Where do you live? .....
8. Mother's highest educational level attained? **O** Middle school **O** Junior High school
   O Senior High School **O** Institute/Tertiary
   O Professional/Technical Education
9. Marital status of parents? **O** Married **O** Divorced **O** Separated **O** Widowed **O** Single/Never married
10. How much money are you given to spend at school in a day? **O** 0-1 cedi **O** 2 cedis **O** 3 cedis
    O 4 cedis **O** 4 cedis **O** ≥5 cedis

Section 2- EXPOSURE FROM SCHOOL ENVIRONMENT
(Please shade the circle appropriate for each response)

11. Is your school located close to a busy road? **O**Yes **O** No
12. If yes, how far is your school from the busy road? **O** ≤ 50m **O** > 50-100m **O** >200-300m **O** >400m

How often are you exposed to the following at school? (Shade those that approximately apply to pupil at school)

13 Dust **O** Never **O** Rarely **O** Sometimes **O** Almost daily
14 Smoke from cigarette **O** Never **O** Rarely **O** Sometimes **O** Almost daily
15.Fumes **O** Never **O** Rarely **O** Sometimes **O** Almost daily
16. Smoke **O** Never **O** Rarely **O** Sometimes **O** Almost daily
17. Noise **O** Never **O** Rarely **O** Sometimes **O** Almost daily

What is the material of ceiling in your classroom?

18. Concrete **O** No **O** Yes
19. Wood **O** No **O** Yes
20. Acoustic board **O** No **O** Yes

21. Asbestos **O** No **O** Yes
22. Slate **O** No **O** Yes

What is the material of walls in the classroom?

23. Wood or Plywood **O** No **O** Yes
24. Painted **O** No **O** Yes
25. Paper wall **O** No **O** Yes
26. PVC plastic wall **O** No **O** Yes
27. Other plastic wall **O** No **O** Yes
28. Textile surface **O** No **O** Yes
29. Not known **O** No **O** Yes

Section 3-EXPOSURE FROM HOME ENVIRONMENT

(Please shade the circle appropriate for each response)

30. Is your home located close to a busy road? **O**Yes **O** No
31. If yes, how far is your home from the busy road? **O** ≤ 50m **O** > 50-100m **O** >200-300m **O** >400m

How often are you exposed to the following at home? (Shade those that approximately apply to pupil at home)

32. Dust **O** Never **O** Rarely **O** Sometimes **O** Almost daily
33. Smoke from cigarette **O** Never **O** Rarely **O** Sometimes **O** Almost daily
34. Fumes **O** Never **O** Rarely **O** Sometimes **O** Almost daily
35. Smoke **O** Never **O** Rarely **O** Sometimes **O** Almost daily
36. Noise **O** Never **O** Rarely **O** Sometimes **O** Almost daily
37. Insecticides **O** Never **O** Rarely **O** Sometimes **O** Almost daily
38. Pesticides **O** Never **O** Rarely **O** Sometimes **O** Almost daily
39. Chemicals (Bleaches, disinfectants) **O** Never **O** Rarely **O** Sometimes **O** Almost daily

What is the material of ceiling in your room?

40. Concrete **O** No **O** Yes
41. Wood **O** No **O** Yes
42. Acoustic board **O** No **O** Yes
43. Asbestos **O** No **O** Yes
44. Slate **O** No **O** Yes

What is the material of walls in the room?

45. Wood or Plywood **O** No **O** Yes
46. Painted **O** No **O** Yes
47. Paper wall **O** No **O** Yes
48. PVC plastic wall **O** No **O** Yes
49. Other plastic wall **O** No **O** Yes
50. Textile surface **O** No **O** Yes
51. Not known **O** No **O** Yes

What is the material of floors in the home?

52. Concrete, tile, marble **O** No **O** Yes
53. Wood/parquet **O** No **O** Yes

54. Bare floor	**O** No	**O** Yes
55. PVC plastic	**O** No	**O** Yes
56. wall-to-wall carpet	**O** No	**O** Yes

Section 4- Cognitive well-being- Circle the corresponding number based on the health profile of the pupil

0 Never experience symptom
1 Occassionally experience symptom but effect not severe
2 Occationnaly experience symptom but effect is severe
3 Frequently experience symptom but effect is not severe
4 Frequently experience symptom but effect is severe

57. **COGNITIVE SYMPTOMS**

a) Poor memory	0 1 2 3 4
b) Confusion	0 1 2 3 4
c) Poor concentration	0 1 2 3 4
d) Difficulty making dicision	0 1 2 3 4
e) Stuttering, stammering	0 1 2 3 4
f) Slurred speech	0 1 2 3 4
g) Learning disability	0 1 2 3 4
h) Inattentiveness	0 1 2 3 4

Section 5: PAPER AND PENCIL IQ TEST

Please get ready for a test in the next 45 minutes.

This questionnaire is to collect data to assess the association between the effects of e-waste on the cognitive function of pupils.

INSTRUCTIONS

1. You have **45 minutes** to answer **60 questions**. This time limit will not be exceeded.
2. The use of calculators is **not** permitted in this test.
3. Do not leave any question unanswered. Answer all questions. Pick only one answer in each question.
4. If you do not know the answer, guess because guessing is part of the test.
5. These questions are purposely designed to test your ability to think and reason.
6. Choose the correct answer by circling the alphabet corresponding to your choice.

Sample Question

Carefully study the following sample question before beginning the test.
In some questions you will be asked to make a comparison.

EXAMPLE:
Which one of the five makes the best comparison? Boat is to water as airplane is to:
(a) Sun (b) Ground (c) Water (d) Sky (e) Tree.

The correct answer is (d) sky. So you will make a circle round the alphabet (d) as shown below.

(a) Sun (b) Ground (c) Water  Sky (e) Tree.

You are now ready to begin the test.

1. **Which one of the five is least like the other four?**
   (a) Bear (b) Snake (c) Cow (d) Dog (e) Tiger
2. **If you rearrange the letters "BARBIT", you would have the name of:**
   (a) Ocean (b) Country (c) State (d) City (e) Animal
3. **Which one of the five designs makes the best comparison?**
   

   (a)  (b)  (c)  (d)  (e) 
4. **Which one of the five is least like the other four?**
   (a) Potato (b) Corn (c) Apple (d) Carrot (e) Bean
5. **Which one of the five designs makes the best comparison?**
   

   (a)  (b)  (c)  (d)  (e) 
6. **John, twelve years old, is three times as old as his brother. How old will John be when he is twice as old as his brother?**
   (a) 15 (b) 16 (c) 18 (d) 20 (e) 21
7. **Which one of the five makes the best comparison?**
   BROTHER IS TO SISTER AS NIECE IS TO:
   (a) Mother (b) Daughter (c) Aunt (d) Uncle (e) Nephew
8. **Which one of the five designs is least like the other four?**
   (a) A (b) Z (c) F (d) N (e) E
9. **Which one of the five makes the best comparison?**
   MILK IS TO GLASS AS LETTER IS TO:
   (a) Stamp (b) Pen (c) Envelope (d) Book (e) Mail
10. **Which one of the five is least like the other four?**
    (a)  (b)  (c)  (d)  (e) 
11. **Which one of the five choices makes the best comparison?**
    LIVE is to EVIL as 5232 is to:
    (a) 2523 (b) 3252 (c) 2325 (d) 3225 (e) 5223
12. **"If some Smaugs are Thors and some Thors are Thrains, then some Smaugs are definitely Thrains." This statement is:**
    (a) True (b) False (c) Neither
13. **Which one of the five designs is least like the other four?**
    (a)  (b)  (c)  (d)  (e) 
14. **Which one of the five makes the best comparison?**
    TREE IS TO GROUND AS CHIMNEY IS TO:
    (a) Smoke (b) Brick (c) Sky (d) Garage (e) House

15. Which one of the numbers does not belong in the following series?

(a) 9 (b) 7 (c) 8 (d) 6 (e) 7 (e) 5 (f) 6 (g) 3

16. Which one of the five is least like the other four?

(a) Touch (b)Taste (c) Hear (d) Smile (e) See

17. Which one of the five designs makes the best comparison?  is to

(a) (b)  (c)  (d)  (e) 

18. Jack is taller than Peter, and Bill is shorter than Jack. Which of the following statements would be most accurate?

(a) Bill is taller than Peter (b) Bill is as tall as Peter

(b) Bill is shorter than Peter (d) It is impossible to tell

19. Which one of the five is least like the other four?

(a) Stocking (b) Dress (c) Shoe (d) Purse (e) Hat

20. Which one of the five makes the best comparison? CAACCAC is to 3113313 as CACAACAC is to:

(a) 13133131 (b) 13133313 (c) 31311131 (d) 31311313 (e) 31313113

21. If you rearrange the letters "RAPIS", you would have the name of:

(a) Ocean (b) Country (c) State (d) City (e) Animal

22. Which one of the designs is least like the other four?

(a)  (b)  (c)  (d)  (e) 

23. Which one of the five makes the best comparison? BULLET IS TO GUN AS BALL IS TO:

(a) Bat (b) Slingshot (c) Cannon (d) Pitcher (e) Catapault

24. If some Bifurs are Bofurs and all Gloins are Bofurs, then some Bifurs are definitely Gloins." This statement is:

(a) True (b) False (c) Neither

25. Which one of the designs is least like the other four?

(a)  (b)  (c)  (d)  (e) 

26. Which one of the letters does not belong to the following series?

(a) A (b) D (c) G (d) I (e) J (f) M (g) P (h) S

27. Which one of the five designs makes the best comparison? 

(a)  (b)  (c)  (d)  (e) 

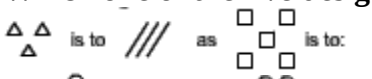
28. The price of an article was cut 20% for a sale. By what percent must the item be increased to again sell the article at the original price?

(a) 15% (b) 20% (c) 25% (d) 30% (e) 40%

29. Which one of the five is least like the other four?

(a) Copper (b) Iron (c) Brass (d) Tin (e) Lead

30. Which one of the five designs makes the best comparison?



(a)  (b)  (c)  (d)  (e) 

31. Which one of the five is least like the other four?

(a) Bottle (b) cup (c) Tub (d) Funnel (e) Bowl

32. Mary had a number of cookies. After eating one, she gave half the remainder to her sister. After eating another cookie, she gave half of what was left to her brother. Mary now had only five cookies left. How many cookies did she start with?

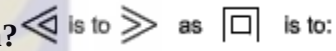
(a) 11 (b) 22 (c) 23 (d) 45 (e) 46

33. Which one of the five is least like the other four?

(a) Wheat (b) Hay (c) Barley (d) Oats (e) Rice

34. Which one of the numbers does not belong is the following series?

(a) 2 (b) 3 (c) 6 (d) 7 (e) 8 (f) 14 (g) 15 (h) 30

35. Which one of the five designs makes the best comparison? 

(a)  (b)  (c)  (d)  (e) 

36. A spaceship received three massages in a strange language from a distant planet. The astronauts studied these messages and found that "Elros Aldarion Elendil" means "Danger Rocket Explosion" and "Edain Mnyatur Elros" means "Danger spaceship Fire" and "Aldarion Gimilzor Gondor" means "Bad Gas Explosion". What does "Elendil" mean?

(a) Danger (b) Explosion (c) Nothing (d) Rocket (e) Gas

37. Which one of the five is least like the other four?

(a)  (b)  (c)  (d)  (e) 

38. Which one of the five makes the best comparison? BELT IS TO BUCKLE AS SHOE IS TO:

(a) Sock (b) Toe (c) Foot (d) Lace (e) Sole

39. Which one of the five designs is least like the other four?

(a)  (b)  (c)  (d)  (e) 

40. John received $.41 change from a purchase in the drugstore. If he received six coins, three of the coins had to be:

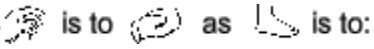
(a) Pennies (b) Nickels (c) Dimes (d) Quarters (e) Half-Dollars

41. Which one of the five designs is least like the other four?

(a)  (b)  (c)  (d)  (e) 

42. If you rearrange the letters "MANGERY", you would have the name of:

(a) Ocean (b) Country (c) State (d) City (e) Animal

43. Which one of the five designs makes the best comparison? 

(a)  (b)  (c)  (d)  (e) 

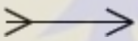
44. "If all Wargs are Twerps and no Twerps are Gollums, then no Gollums are definitely Wargs." This statement is:
(a) True (b) False (c) Neither

45. Which one of the five is least like the other four?
(a) Horse (b) Kangaroo (c) Zebra (d) Deer (e) Donkey

46. Which one of the designs does not belong in the following series?
(a)  (b)  (c)  (d)  (e) 

47. Which one of the five makes the best comparison?
FINGER IS TO HAND AS LEAF IS TO:
(a) Tree (b) Branch (c) Blossom (d) Twig (e) Bark

48. John's mother sent him to the store to get 9 large cans of peaches. John could only carry 2 cans at a time. How many trips to the store did John have to make?
(a) 4 (b) 4½ (c) 5 (d) ½ (e) 6

49. Which one of the five designs is least like the other four?
(a)  (b)  (c)  (d)  (e) 

50. Which one of the five makes the best comparison? FOOT IS TO KNEE AS HAND IS TO:
(a) Finger (b) Elbow (c) Toe (d) Leg (e) Arm

51. Which one of the five designs is least like the other four?
(a)  (b)  (c)  (d)  (e) 

52. Mary was both 13th highest and 13th lowest in a spelling contest. How many people were in the contest? (a)13 (b) 25 (c) 26 (d) 27 (e) 28

53. Which one of the five makes the best comparison? WATER IS TO ICE AS MILK IS TO:
(a) Honey (b) Cheese (c) Cereal (d) Coffee (e) Cookie

54. Which one of the numbers does not belong is the following series:
(a) 1 (b) 2 (c) 5 (d) 10 (e) 13 (f) 26 (g) 29 (h) 48

55. Which one of the five is least like the other four?
(a) Ham (b) Liver (c) Salmon (d) Pork (e) Beef

56. "If all Fleeps are Sloops and all Sloops are Loopies, then all Fleeps are definitely Loopies." This statement is:
(a) True (b) False (c) Neither

57. Which one of the five designs makes the best comparison?
(a)  (b)  (c)  (d)  (e) 

58. Which one of the five is least like the other four?
(a) Inch (b) Mile (c) Acre (d) Yard (e) Foot

59. Which one of the five designs makes the best comparison?
(a)  (b)  (c)  (d)  (e) 

60. A fish has a head 9 cm long. The tail is equal to the size of the head plus one-half the size of the body. The body is the size of the head plus the tail. How long is the fish?
(a) 27 cm (b) 54 cm (c) 63 cm (d) 72 cm (e) 81 cm

APPENDIX 4- Responses to the IQ Test

1. B
2. E
3. D
4. E
5. B
6. E
7. E
8. E
9. C
10. E
11. C
12. A
13. D
14. C
15. G
16. D
17. B
18. D
19. A
20. D
21. D
22. A
23. A
24. A
25. B
26. H
27. D
28. B
29. C
30. B
31. D
32. C
33. B
34. A
35. A
36. C
37. A
38. D
40. D
41. C
42. D
43. B
44. E
45. B
46. B
47. D
48. D
49. C
50. B
51. E
52. C
53. B
54. A
55. C
56. A
57. A
58. C
59. E
60. D

APPENDIX 5- Wechsler Intelligence Scale for Children 6-16+ years

AGE						IQ
11	**12**	**13**	**14**	**15**	**16+ Adult**	
1	3	6	8	10	12	66
2	4	7	9	11	13	68
3	5	8	10	12	14	70
4	6	9	11	13	15	72
5	7	10	12	14	16	74
6	8	11	13	15	17	76
7	9	12	14	16	18	78
8	10	13	15	17	19	80
9	11	14	16	18	20	82
10	12	15	17	19	21	84
11	13	16	18	20	22	86
12	14	17	19	21	23	88
13	15	18	20	22	24	90
14	16	19	21	23	25	92
15	17	20	22	24	26	94
16	18	21	23	25	27	96
17	19	22	24	26	28	98
18	20	23	25	27	29	100
19	21	24	26	28	30	102
20	22	25	27	29	31	104
21	23	26	28	30	32	106
22	24	27	29	31	33	108
23	25	28	30	32	34	110
24	26	29	31	33	35	112
25	27	30	32	34	36	114
26	28	31	33	35	37	116
27	29	32	34	36	38	118
28	30	33	35	37	39	120
29	31	34	36	38	40	122
30	32	35	37	39	41	124
31	33	36	38	40	42	126
32	34	37	39	41	43	128
33	35	38	40	42	44	130
34	36	39	41	43	45	132
35	37	40	42	44	46	134
36	38	41	43	45	47	136
37	39	42	44	46	48	138
38	40	43	45	47	49	140
39	41	44	46	48	50	142
40	42	45	47	49	51	144
41	43	46	48	50	52	146
42	44	47	49	51	53	148
43	45	48	50	52	54	150
44	46	49	51	53	55	154
45	47	50	52	54	56	158
46	48	51	53	55	57	160
47	49	52	54	56	58+	165+

APPENDIX 6-Wechsler Classification of Intelligence Quotient

Very superior/Genius	130 and Above
Superior	120-129
High average	110-119
Average	90-109
Low average	80-89
Boarder line	70-79
Extremely low	69 and below