

IMPACT OF COPPER, LEAD, IRON AND ZINC ON OCCUPATIONAL PHOTOCOPIER OPERATORS AND REPAIRERS IN THE UNIVERSITY OF BENIN COMMUNITY- A PILOT STUDY

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Abstract

Aim: Photocopying serves as a good source of employment to many Nigerian youths and its importance cannot be overemphasized. Photocopiers are used on a regular basis without any protective measure. This study seeks to ascertain the complexity of copper, lead, iron and zinc accumulates in the body of occupational users of photocopiers and their possible health hazards.

Methods: Seventy subjects including tests and controls (non users of photocopiers) of 18 years and above were recruited for the study. Plasma was analysed for copper, lead, iron and zinc using Flame Atomic Absorption Spectrophotometer.

Results: The mean \pm standard error of mean of copper, lead and iron in professional operators of photocopiers (91.50 ± 3.66 , 0.00 ± 0.00 , and 100.2 ± 3.18 respectively) were surprisingly significantly lower when compared with their controls (non-users) (161.48 ± 8.78 , 0.01 ± 0.00 and 140.22 ± 8.78 respectively). The mean \pm standard error of zinc was slightly higher in occupational users of photocopiers (98.45 ± 1.59) when compared with controls (98.11 ± 4.39) though this was not significant.

Conclusion: Plasma copper, lead and iron were significantly lower in operators of photocopiers who come in contact with toner powders than in their control while plasma Zinc was slightly higher.

Key words: Toxic metals, FAAS, Photocopiers.

INTRODUCTION

Photocopying serves as a good source of employment to many Nigerian youths currently owing to the current state of unemployment in Nigeria. They are used on a regular basis in companies, schools and business centres. A photocopier works based on basic xerographic principles (Armbruser *et al.*, 1996). Photocopiers use powdered toners for printing characters and images. The toner mainly consist of carbon black (7%) polycyclic hydrocarbons (PAHs,) styrene, magnetite, nitropyrenes, benzene, toluene, other volatile substances and low melt polymer resins mixed with minute steel, silica or ferrite beads besides these, ozone, nitrogendioxide, volatile organic compound like1, 1-biphenyl, p-di-cholorobenzene,

pyrolbenzene and tetra-chloroethylene aldehydes are also released into the atmosphere by the machine while operating (Gadhia *et al.*, 2005). The following metals have been detected in toners and emission of copying machines to a considerable amount. These includes; Arsenic, Cadmium, cobalt, Lead, Chromium, Copper, Iron, Nickel, Mercury, Selenium, Vanadium, Zinc. Exposure to toner powder may occur via dermal routes by direct skin or eye contact, respiration by inhalation or ingestion if toner powder is swallowed accidentally (Fraga, 2005). Copper, Zinc and iron are considered as trace elements, because they are essential and required in very limited quantity. Trace elements are essential components of biological structures, but at the same time they can be toxic

at concentrations beyond those necessary for their biological functions (Bonham *et al.*, 2005). Copper (Cu) is one of the essential micronutrients and it is necessary for its wide range of metabolic processes. Copper is a cofactor for several important enzymes, including cytochrome-c oxidase (in the mitochondrial electron transport chain), superoxide dismutase (part of the protection against reactive oxygen species) and lysyl oxidase, which is needed for the cross-linking of collagen and elastin. Copper is vitally important for brain function. In addition to cytochrome c oxidase, which is essential for energy generation in the brain, copper is present in dopamine β -monoxygenase, an enzyme involved in the catecholamine synthesis pathway, and in peptidyl α -amidating monoxygenase, which modifies various peptide neurotransmitters. Although Copper is a required element, at elevated levels it becomes toxic. Copper toxicity is rare in human due to the homeostatic mechanisms present in human, but exposure to excessive levels of copper can result in a number of adverse health effects such as liver and kidney damage, anaemia, immunotoxicity and developmental toxicity (Bonham *et al.*, 2005). Iron is a component or cofactor of many critical proteins and enzymes such as haemoglobin, myoglobin, catalase, xanthine oxidase, aconitases, reduced nicotinamide adenine dinucleotide, ribonucleotide reductase, peroxidases and cytochrome oxidase (Kohgo *et al.*, 2008). Iron serves as a carrier of oxygen to the tissues from the lungs by red blood cell haemoglobin, as a transport medium for electrons within cells and as an integral part of important enzyme systems in various tissues. Iron overload induces organ damage in liver, heart, pancreas, thyroid and the central nervous system. The main cause of this organ damage is due to over production of Reactive Oxygen Species (ROS) in the presence of excess Iron (Goyer, 1995). Zinc is an essential metal, it is ubiquitous in the environment so it is present in most food, water and air (WHO, 2010). It is required for the optimum function of as many as 300 enzymes. Numerous proteins, enzymes and transcription factors depend on zinc for their function. Zinc is an essential component of hundreds of proteins and metalloenzymes including alkaline phosphatase, lactate dehydrogenase, carbonic anhydrase, carboxypeptidase, and DNA and RNA polymerases found in most body tissues. Zinc plays an important role as ionic signalling in

large number of cells and tissues. Toxicity of zinc by inhalation causes metal-fume fever. This disorder has been most commonly associated with inhalation of zinc oxide fumes. Effects of metal fume include fever, chills, gastroenteritis, substernal chest pain, and cough (Ibrahim *et al.*, 2006). Prolonged ingestion has been shown to result in copper deficiency characterized by hypocupremia, anaemia, leucopaenia and neutropaenia; some subjects additionally report headache, abdominal cramps and nausea. Ingestion of excess zinc also causes neurotoxicity and cardiovascular toxicity with symptoms such as lethargy, light-headedness, staggering, and difficulty in writing clearly, anxiety, depression, somnolence and comatose (WHO 2010, Ibrahim *et al.*, 2006). Lead is a heavy metal with various industrial uses but no physiologic use. Any evidence of lead within the human body therefore can be viewed as contamination (Ahamed *et al.*, 2007). Lead-induced hypertension is the most common symptom attributed to lead exposure in adults, but patients can also develop anaemia, gastric colic, muscle and joint pain, decreased fertility, renal failure and peripheral motor neuropathy. The most common childhood presentation of lead poisoning is central neurotoxicity which includes anaemia, peripheral motor neuropathy, and Gastrointestinal (GI) complaints, such as anorexia, vomiting and abdominal pain and growth delay. Lead readily crosses the placental and has been reported to cause foetal toxicity (Ahamed *et al.*, 2007).

Motivation for the Study

Recent studies showed that Toners contain toxic metals such as iron, copper, zinc and lead. The use of photocopiers is on the increase in Nigeria, mostly in higher institutions of learning. Occupational operators of photocopiers spend long working hours. During the work process, the toner dust may become airborne for a variety of reasons, toner dust spilled inside the machine becomes airborne by passing through the ventilation into the room or they may be spread by mouth blowing of excess toners by users in attempts to change the toners especially during refill. These operators do not use protective measures such as face mask and thus are liable to inhale toner dust. This work investigated the health hazards associated with the use of photocopiers by measuring the levels of lead, zinc, iron and copper in the blood of people whose occupation depends on regular use of photocopiers.

MATERIALS AND METHODS

Geographical Location: The study was carried out at the University of Benin, Ugbowo, Benin City Nigeria. Four shopping complexes with a large number of photocopiers were chosen. This was because of proximity and availability of a large number of subjects being a pilot study.

Study Population and Sample Size

The study population is composed of adults of either sex of age 18years and above. All adults involved in this study were occupationally exposed to photocopier toner for a minimum of 6 months and had not been diagnosed of any chronic disease or terminal illness. The study group comprised of 44 copying machines operators, 6 photocopying machine repairers. Twenty (20) adults who were not occupationally exposed to photocopier toners were included in the study as a control group

Sampling of Blood

All blood samples were collected by skilled hands through venipuncture with sterile disposable needles and syringes. 4ml of venous blood was collected and transferred into Lithium heparinised tube. These blood samples were centrifuged at 3000rpm for 5 minutes and the resultant plasma was transferred into a sterile plain container. The samples were stored at -20°C. Prior to the blood collection, each individual gave an informed consent. A questionnaire about his personal detail, working condition, habits (such as smoking) and medication was given. Heavy metals were analysed by atomic absorption spectrophotometry (Buck Scientific 210VGP Atomic Absorption Spectrophotometer) at the Analytical Services Laboratory of International Institute of Tropical Agriculture (IITA), Ibadan.

Statistical Analysis

The statistical analysis was performed using the Statistical Product and Service Solutions (SPSS) version 21.0, 2012. The statistical methods included the mean, standard error of mean, Variance and range. The Student t-test was used for comparisons of data. Levene's test was used to verify homogeneity of variances. A Pearson Correlation model was used to determine correlation between multiple data. A value of $p < 0.05$ was considered to be significant, a value of $p < 0.01$ was considered to be highly significant and a value of $p > 0.05$ was considered not significant.

RESULTS

Table 1: Demographic information of study participants

Occupation	Number	%
Photocopy operators	50	71
Control	20	29
Total	70	100
Gender	Operator	Control
Male	21 (30%)	12 (17.14%)
Female	29 (41.43%)	8 (11.43%)

The table above shows the demographic data of subjects involved in the study. It shows their gender and occupation with corresponding percentage.

Table 2: Age of operators and control

Age	<18	18-25	25-35	>35
Operators	1	15	28	6
Control	-	18	2	-

This shows the age limits of each participant, their occupation and number of participant who fall in each age limit.

Table 3: Average working hours of participants

Working Hours	<3	3-6	6-10	>10 hr	Unknown
Number of participants	1	10	23	14	2
Year working with photocopier	<1yr	1-5yr	6-10yr	>10yr	Unknown
Number of participant	10	24	6	5	3

This table shows the average working hours of photocopy operators and the number of years worked with a mean working hour of 8 hours.

Table 4: Plasma Levels of Cu, Fe and Zn in Photocopiers and Control Subjects

Parameter	Operators (Mean±SEM)	Control (Mean±SEM)	Significance
Pb (ug dl)	0.00±0.00	0.01±0.00	** p< 0.01
Cu (ug dl)	91.50±3.66	161.48±8.78	**p< 0.01
Fe (ug dl)	100.2±3.18	140.22±8.78	**p< 0.01
Zn (ug dl)	109.45±1.59	98.11±4.39	p> 0.05

Table 4 shows the mean \pm standard error of Lead, Copper, Iron and Zinc in photocopier operators and non-operators. Lead, Cu and Fe were significantly lower in operators than in controls ($p<0.01$) while zinc plasma levels were higher in operators than in control though this was not statistically significant ($p>0.05$).

DISCUSSION

In this study, plasma levels of lead, iron, copper and zinc in 50 occupational operators of photocopiers and 20 non-users (controls) were estimated. The mean \pm standard error of mean of lead, copper and iron in occupational operators of photocopiers were significantly lower when compared with their controls (non-users). The mean \pm standard error of mean of zinc was slightly higher in occupational operators of photocopiers when compared with controls though this was not significant. Operators of photocopier subconsciously inhale and ingest toner powder during the course of their work. It has also been observed that these users do not use protective materials such as face masks to prevent inhalation. Lead was negatively correlated with Zinc and this was not significant. It means that a slight increase in plasma Zinc may bring about a slight decrease in lead and vice versa. This is in line with Leelakunakorn *et al.*, 2005 who suggests that zinc reduces lead induced oxidative stress and also competes with lead for similar binding site. Competitive binding to metallothioneins like transport proteins in duodenum suggest the ability of Zinc to reduce Lead absorption (Ercal *et al.*, 2001). Aside Lead and Zinc that were negatively correlated, the other individual metals were significantly positively correlated with each other. Lead was found to positively correlate with iron, (Critical $r_{(P<0.05)} = 0.24447$). In other words, plasma iron concentration increases as Lead Concentration increases. Lead competes with iron for binding sites (Papanikolaou *et al.*, 2005). This may be responsible for the significant positive correlation of lead and iron which may occur when lead displaces iron from tissue binding

sites. On the other hand, this may be responsible for the decreased iron concentration observed in the test group as compared with the control group which may be due to interference of lead with intestinal iron absorption. It can also be inferred from the correlation that constant and persistence exposure to the toner powder may result in lead accumulation in the future. In the mechanism of metal induced oxidative stress, lead is among the redox-inactive metals which can directly interfere with the activity of antioxidants such as glutathione reductase (GR) due to the presence of disulphide bond in its structure. Other antioxidant enzymes which remove peroxides superoxide radicals are also potential target of metals such as lead (Hall *et al.*, 1976). This may lead to oxidative stress and associated pathological conditions. Zinc was slightly increased in the test subject than the controls while other metals were significantly lower. The lower content of the other metals may be as a result of antagonism by Zinc. Zinc and Lead interact in an antagonistic manner. Research indicates that Lead and zinc compete for uptake in the intestine, perhaps on the same metallothioneins-like transport protein (Fischer *et al.*, 1981). Studies show that a high zinc intake decreases tissue lead levels in laboratory animals (Ercal *et al.*, 2001). Lead has no physiological use so a reduced plasma lead is a good development as increased plasma lead has been known cause acute neuropathy, nephropathy, encephalopathy and adversely affecting the central nervous system (Couszy *et al.*, 1993, Miller 1994). In the test group, plasma copper was lower than the control. A reduced copper may also be as a result of antagonism by zinc. Researchers propose that zinc may interfere with copper absorption by competing

for binding sites on metallothionein in the intestinal mucosal cells (Cousins 1994). Research indicates that zinc also interacts indirectly with copper to decrease copper absorption. Zinc interacts with a nuclear protein that governs the synthesis of metallothionein in intestinal mucosal cells. High levels of zinc increase the level of intestinal metallothionein, which in turn binds to copper more strongly than zinc, creating a copper-metallothionein complex that is poorly absorbed (Madsen & Gitlin 2007;Zucconi *et al.*, 2007). This shows that a slight increase in Zinc brought about a deficiency in copper. Copper is present throughout the brain and is most prominent in the basal ganglia, hippocampus, cerebellum, numerous synaptic membranes, and in the cell bodies of cortical pyramidal and cerebellar granular neurons (Provan 1999). Enzymes in the central nervous system that depend on copper for their function include tyrosinase, peptidylglycine-amidating mono-oxygenase, copper/zinc superoxide dismutase, ceruloplasmin, hephaestin, dopamine-hydroxylase, and cytochrome *c* oxidase (Beard 2001).Copper deficiency have been known to cause several disorders of the central nervous system including ataxia, tremor, cronic seizure, hypomyelination or demyelination and reduced levels of sphingolipids.The decreased copper thus implies that the test group are at risk of developing these pathological conditions. Low copper levels can be found in Aceruloplasminaemia, Menkes disease. Iron levels in sample test were lower than in control. Iron is a component or cofactor of many critical proteins and enzymes such as haemoglobin, myoglobin, catalase, xanthine oxidase, aconitase, reduced nicotinamideadenine dinucleotide, ribonucleotide reductase, peroxidases, and cytochrome oxidase (Kohgo *et al.*, 2008). Functions of iron include involvement in energy metabolism, gene regulation, cell growth and differentiation, oxygen binding and transport, muscle oxygen use and storage, enzyme reactions, neurotransmitter synthesis, and protein synthesis (CDC 1998). Low plasma iron is seen in diseases such as iron deficiency anaemia (IDA) this can be caused by deficient iron absorption.

The symptoms include tiredness, fatigability, headache, body ache, paraesthesia and lack of concentration for months or years before medical attention is sought. Apart from the signs and symptoms of anaemia in general, there are certain features which are specific to IDA – like smooth tongue, angular stomatitis, brittle, flattened or spoon shaped nails (koilonychia). Some patients develop upper esophageal mucosal web formation with resultant dysphagia. The combination of splenomegaly, koilonychia and dysphagia in a case of IDA has been described as Plummer- Vinson or Paterson-Kelly syndrome.

CONCLUSION

Plasma copper, lead, and iron did not accumulate in the body of operators of photocopiers who came in contact with toner powders instead they were significantly lower in these operators than in their control while plasma zinc was slightly higher. The low copper, lead and iron may be as a result of antagonism with zinc. This preliminary finding provides a basis for further investigation into the mechanism through which plasma copper, lead and iron exert their effects and potential use in the management and monitoring of organ toxicity and it may hold promise as a future source of a drug of clinical relevance. Further studies could be done to detect if other substances present in toners such as polycyclic hydrocarbons (PAHs,) styrene, magnetite, nitropyrenes, benzene, toluene could be responsible for this reduction or what factor on the job that could have brought about this reduction.

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