Toxicity of Vanadium, Cadmium, Chromium and Iron on the Kidney Status of Occupational Photocopier Operators at the University of Benin, Benin-City, Nigeria- A Pilot Study.

Osadolor B.H* and Ezegbogu M.O

Department of Medical Laboratory Science, University of Benin, P.M.B.1154, Benin City, Nigeria.

Abstract

There is conflicting information on the adverse health effects of photocopier toner powder on operators.This study aim to determine the possible nephrotoxic effects of some commercially available photocopier toners and establish the reference ranges of the selected heavy metals (vanadium, cadmium, chromium and iron) for residents of Benin City, Edo state, Nigeria. Blood samples were collected from photocopier operators and technicians resident in Benin City, Nigeria. Renal function and the levels of heavy metals of theses samples were assessed. The biochemical parameters used to evaluate renal function include: urea, creatinine and electrolytes. Heavy metals were analyzed by atomic absorption spectrophotometry, sodium and potassium ions were analyzed by flame emission photometry, urea was analyzed by the urease-betherlot method, creatinine was analyzed using the Jaffe technique while chloride and bicarbonate ions were analyzed using the Schales and Schales method and acid-base back titration respectively. Plasma levels of cadmium and iron were found to be significantly lower ($P<0.01$) in the test subjects relative to their controls. Urea and potassium ions were found to be significantly elevated in the test subjects relative to their controls at $P<0.01$. Creatinine, chromium and vanadium were also found to be elevated in test subjects relative to their controls; though these were not statistically significant at $P>0.05$. The results obtained from this study are suggestive of renal damage. Also, prolonged exposure to photocopier toner powder may be a risk factor for the development of iron deficiency anaemia.

Key words: vanadium, cadmium, chromium, iron, photocopier

INTRODUCTION: As a result of rapid progress in office and home automation, the number of instruments used for computation, information, and communication have increased steadily in developed and developing countries. Among these are laser printers, facsimile machines, and photocopiers, which use powdered toner for printing characters and images. Thus, a substantial section of the population may currently be exposed to toner powder. Photocopier operators and technicians changing their toner cartridges or maintaining these devices come into direct contact with considerable amounts of toner powder, and thus belong to the population groups that have frequent high exposure to toner dust. Exposure to toner powder may occur via dermal routes by direct skin or eye contact, inhalation, or ingestion if toner powder is swallowed accidentally (Furkawa *et al*., 2002).

Photocopier toner powders consist of very small particles of a thermoplastic polymer, usually a styrene-acrylate copolymer, which is fixed onto the paper by fusion at about 170^0C. The main constituents of toner- carbon black and Iron oxide may contain impurities, namely polycyclic aromatic hydrocarbons (PAHs) and heavy metals (Jungnickel *et al*., 2002).

Heavy metal toxicity represents a common but poorly recognized, yet clinically significant, medical condition. If undetected or inappropriately treated, heavy metal toxicity can result in significant morbidity and mortality (Goyer, 1996). This is paucity of information on the toxicity of photocopier toner on the renal system via these selected heavy metals, hence the necessity for this study.

***Corresponding author: E-mail:** humphrey.osadolor@uniben.edu **Phone:** +2347060813792

MATERIALS AND METHODS

Study Area and Population: This study was carried out within the University of Benin business centre. University of Benin is located in Benin-city, Edo state in the south-south geographical region of Nigeria.

Sample Size: Forty-four (44) photocopier operators and six (6) photocopier technicians between 18 and 35 years of age were recruited for the study. The sample size was obtained using the formula below:

$$S = \frac{X^2 NP(1-P)}{d^2(N-1)+X^2P(1-P)}$$

Where, S= Sample size, X^2= Table value or Chi-square at df =1, N= Total population,

P= Population proportion (assumed 0.5), d= Degree of accuracy (0.1)

Also, twenty (20) individuals who were neither photocopier users nor technicians (controls) between the ages of 18 and 27 years of age were arbitrarily recruited for the study.

Inclusion and Exclusion Criteria: Individuals who have used photocopier machines and changed their toner powders themselves for a minimum of six (6) months were included for the study while individuals who had neither used photocopiers nor had passively been exposed to photocopier toner dust were excluded from the study and consequently used as control. Smokers were also excluded from this pilot study

Collection of Samples: Four milliliters of blood was collected by venipuncture from each of the subjects using a sterile disposable needle and syringe; this was transferred into a clean Lithium heparin specimen container while avoiding haemolysis. Plasma was promptly separated from whole blood and stored at -20^0C. The parameters analyzed for in each of the samples include: Cadmium, Chromium, Vanadium, Iron, Sodium ions, Potassium ions, Chloride ions, Bicarbonate ions, Urea and Creatinine.

Renal Function Tests: The parameters analyzed for the assessment of renal function include: Urea, Creatinine, Sodium, Potassium, Chloride and Bicarbonate ions. Urea was analyzed using the urease-berthelot method (Mackay and Macky, 1927), while creatinine was analyzed using the Jaffe reaction (Tausky, 1927). Sodium and Potassium ions were analyzed by flame emission photometry. Chloride ion estimation was done using the Schales and Schales method (Schales and Schales, 1941), while bicarbonate ion was estimated by acid-base back titration (Van Slyke and Aulle, 1977). Heavy metals were analyzed by atomic absorption spectrophotomtery (Buck Scientific 210VGP Atomic Absorption Spectrophotometer

STATISTICAL ANALYSIS: The statistical analysis was done using Statistical package for the social Sciences (SPSS) for Analysis of variance (ANOVA),Student t-test and Mean ± SEM

RESULTS

Table 1 shows the concentration of heavy metals and renal function parameters in both the test and control subjects.

Table 1: T-test table showing significance of heavy metal and renal function parameters in test and control subjects

Analytes	Sample test (Mean±SEM)	Sample control (Mean±SEM)	p-Value	Significance
V(µg/dl)	0.01±0.00	0.01±0.00	0.881	p>0.05
Cd (µg/dl)	0.07±0.00	0.01±0.00	0.000	**P<0.01
Cr (µg/dl)	0.01±0.01	0.01±0.00	0.691	p>0.05
Fe (µg/dl)	140.22±8.78	100.15± 3.18	0.000	**P<0.01
Urea (mg/dl)	35.06±2.36	24.35±1.49	0.007	**P<0.01
Na (mmol/L)	140.26±0.78	140.45±1.08	0.893	p>0.05
K (mmol/L)	4.52±0.14	3.77±0.09	0.001	**P<0.01
Cl (mmol/L)	104.12±0.90	106.45±1.14	0.151	p>0.05
HCO3(mmol/L)	21.72±1.08	21.75±0.43	0.986	p>0.05
Creatinine(mg/dl)	0.97±0.04	0.92±0.03	0.388	p>0.05

* p>0.05- Not Significant **p<0.01- Highly Significant

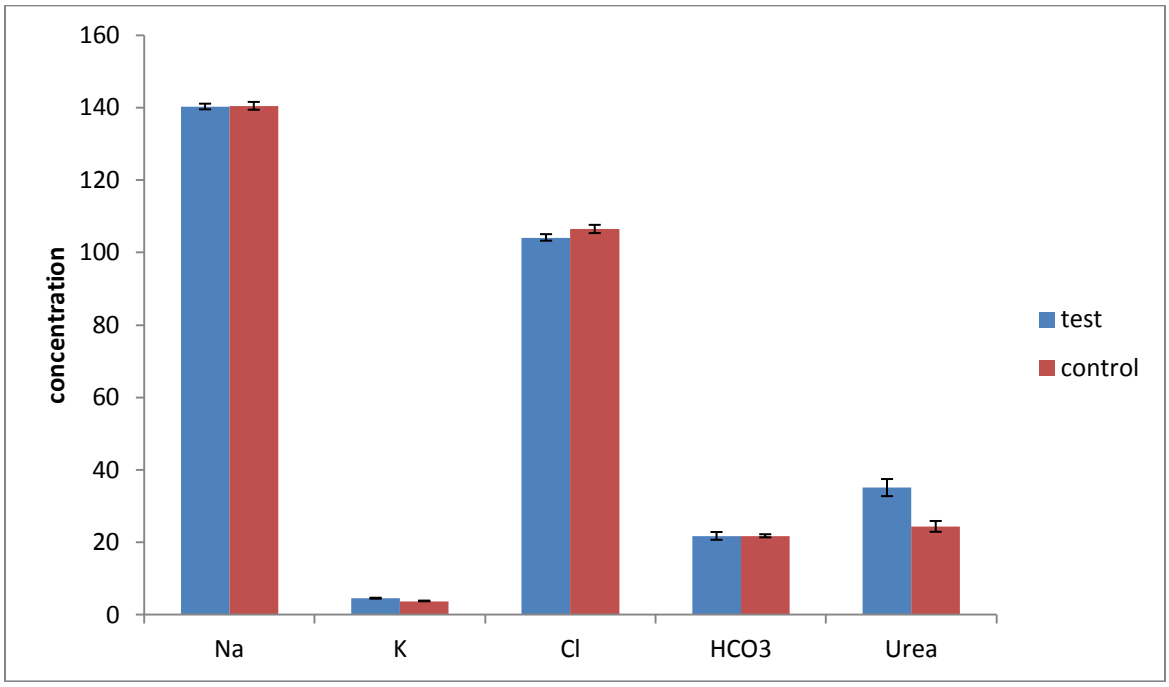

Fig.1: Graph showing plasma levels of urea, sodium, potassium, chloride and bicarbonate ions in test and control subjects.

Figure 1 is a paired plot representing the plasma levels of Sodium ions, Potassium ions, Chloride ions, Bicarbonate ions and urea in test and control subjects. Bars represent mean ± SEM of plasma Sodium ions, Potassium ions, Chloride ions, bicarbonate ions and urea concentrations in both test and control groups respectively.

DISCUSSION: Until now, the adverse effects of toner powders used in photocopiers on humans have been considered to be minimal. However, several reports have suggested possible significant adverse health effects as a result of toner dust inhalation. From this study, the toxic effect of photocopier toner dust on renal function has been established. As shown from table 1, Cadmium and Iron were higher in test subjects than control subjects at $P<0.01$. Vanadium and chromium on the other hand were slightly elevated in test than control subjects although this was not statistically significant>0.05 .Renal function was found to be impaired in the test subjects relative to their controls as evidenced by the significant elevations of plasma potassium ions and urea concentrations observed among the test subjects at $P<0.01$. Occupational exposure of humans to heavy metals may have long term deleterious effects on the liver and renal function (Orisakwe *etal*; 2007). Similar to earlier works of (Osadolor, *et al*; 2013 and Orisakwe *et al*; 2007) in which there were increases in serum levels of cadmium and lead amongst occupational painters and paint factory workers, the increases in the serum cadmium and iron levels in this findings may actually pose some renal and other health challenges to photocopier operators and technicians who do normal routine servicing/repairs of these photocopier machines.

Iron deficiency is expected to increase cadmium absorption (Elsenhans *et al.*, 1997). This report showed a highly significant positive correlation between plasma iron and cadmium concentrations at $P<0.01$ which is inconsistent with the observation made by Elsenhans *et al*., (1997), as elevation of plasma iron seemed to be associated with a concomitant increase in blood cadmium levels in the control group. Furthermore, according to Elsenhans *et al*., (1997), there exists an inverse relationship between plasma iron and cadmium levels; but this study has shown a direct relationship between plasma iron and cadmium levels in both test and control groups as evidenced by joint elevation

and reduction of these two metals in both control and test groups respectively. Nonetheless, the mechanism responsible for this metal-metal interaction is beyond the scope of this work. Furthermore, chromium has been found to be present in photocopier toner powder (Degussa 1998); increase in chromium levels in test subjects in this study may be due to the prolonged use of photocopier toner, since the highest levels of chromium were observed in individuals who have had an exposure time of at least five years.

Vanadium was also found to be high in test subjects relative to control subjects; this was however, not statistically significant at $P>0.05$. This slight elevation may be due to the occupational exposure to toner dust since vanadium has been found to be present in toner (Degussa, 1998). Furthermore, a slight negative correlation between plasma vanadium and iron concentrations was observed; thus, elevation of plasma vanadium levels observed in test subjects may be responsible for the correspondingly low plasma iron levels observed in these subjects as a result of competition of these two ions for transferrin; since vanadium is also transported by transferrin (Halberstam *et al.,* (1996).

A reduction in plasma iron was observed in test subjects relative to control subjects; this suggests that individuals exposed to toner dust may be at risk of iron deficiency. From the results obtained, the lowest value for plasma iron (67.35µg/dl) was observed in an individual who had been exposed for more than ten years. In this study, of all the individuals with relatively low iron values; 62.5% had a 1-5 year exposure period, 25% had been exposed for 6-10 years, while 12.5% had been exposed for more than ten years. Furthermore, since the lowest value of plasma iron was observed in an individual who had been exposed for more than ten years, it could thus be inferred that the low iron values obtained in test relative to control subjects may be due to prolonged exposure to photocopier toner dust.

Additionally, this study has shown considerable renal damage in test subjects as there was significant elevation of K^+ and urea ($P<0.01$). Renal damage observed in this study may be due to the re-use of photocopier toners since Odokuma and Okey (2005) have observed that the re-use of photocopier toners may lead to the formation of modified products which are slightly more recalcitrant than fresh ones. It was also observed that photocopier operators who had worked for more than ten years had history of irritation (nasal, throat and chest) and light headedness. Some operators who had worked for more than six years alongside those who had a 6-10 hour daily exposure also complained of headaches and light headedness though with reduced frequency. All the photocopier technicians also complained of respiratory irritations. These symptoms are consistent with those described for acute heavy metal toxicity (Samara and Sinert, 2006).

CONCLUSION: Most of the reports available in literature on the toxicity of photocopier toners have been restricted to just Xerox toners. Also, there is paucity of information on the nephrotoxicity of photocopier toners. This report has shown evidence of renal damage in photocopier operators and technicians as proven by the elevations of plasma urea and potassium ion concentrations ($P<0.01$) relative to their control subjects. It has also been shown that individuals chronically exposed to photocopier toner dust may be at risk due to accumulation of iron and cadmium. In addition to renal damage; it was also observed that all the photocopier technicians recruited in this study complained of respiratory tract irritation.

RECOMMENDATION: Evidence from this research work has shown that persistent exposure to photocopier toner dust may cause renal damage in the long run; thus, operators and technicians should minimize direct contact with photocopier toner whenever possible. Operators and technicians who change their toner powders themselves should use protective devices/clothing (such as overalls, hand gloves and nose masks) while changing their toners. More so, since 90% of the subjects recruited for this study used Minolta photocopier toner, it is thus recommended that further studies be carried out using other commercially available photocopier toner brands in order to further assert these claims.

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