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Hepatorenal-toxicities Accompanying Exposure to Indoor Air Pollutants in Chemical Storekeepers at an International Market

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ABSTRACT: Various activities in chemical stores such as production, packaging, repackaging, offloading, and storing of chemicals can emit toxic chemicals into the ambient air which may be detrimental to health. This research work aimed to determine whether or not there is hepatoxicity and nephrotoxicity in chemical storekeepers. A total of twenty male adult storekeepers of four chemical stores were used as subjects. Four male storekeepers of a garment store 1km from the chemical stores of the same market were used as control subjects. Heavy metals in the indoor air of the shops and the blood samples of the subjects were determined using an atomic absorption spectrophotometer while an aerocet analyzer was used for the measurement of particulate matter. Kidney and liver function tests were carried out on the serum of subjects using standard analytical test kits. Concentrations of all the assayed heavy metals in the ambient air of the chemical stores and the blood samples of chemical storekeepers were significantly higher ($p<0.05$) than in the controls. Particulate matter concentrations in all the chemical stores increased significantly ($p<0.05$). Serum urea, creatinine, sodium ion, potassium ion, chloride, and bicarbonate were significantly elevated ($p<0.05$) in the chemical storekeepers compared to control subjects. Concentrations of serum bilirubin and liver enzymes were significantly elevated ($p<0.05$) while total protein and albumin concentrations were significantly decreased ($p<0.05$) in the majority of the chemical storekeepers compared to the control subjects. There were strong indications of renal and hepato-toxicities in the chemical storekeepers at Ariaria International Market.

INTRODUCTION

Chemical stores are shops or warehouses that store fine and heavy chemicals for sale. The chemical stores in the Ariaria international market, Aba, deal with virtually all kinds of chemicals including laboratory, medical, and industrial chemicals. The storekeepers are in charge of the day-to-day running of the stores which involves sales of the chemicals to buyers. They have their sitting position inside the stores and stay inside them almost throughout the whole business day. Ariaria is one of the busiest International Markets in Africa, opens for business for eleven hours (6am to 5pm) every day except on Sundays. The storekeepers of chemical stores in this market may be chronically exposed to chemical pollutants.

Studies on occupational health and safety have shown that pollutants generated at workplaces can trigger tissue

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and organ dysfunction and injury [1-7]. Of greater concern are the workers in the chemical industries and other chemical allied workplaces. This is because various activities in these workplaces such as production, packaging, repackaging, offloading and, storing of chemicals can emit toxic chemicals into the ambient air which may be detrimental to health [8].

Toxic substances enter the body through the eyes, skin, digestive tract, and the pulmonary system and get to the liver as blood drains through the portal vein. The concentration of toxicants is always higher in the liver than in other tissues. As these toxicants accumulate in the liver, they exert detrimental effects on the function of the liver and also cause liver injury [9]. On the other hand, nephrotoxicity can occur from direct or indirect effects of exposure to industrial and environmental chemicals.

The liver function test is a group of tests that measures liver enzymes (aspartate aminotransferase, alkaline phosphatase, alanine aminotransferase, gamma-glutamyltransferase), total protein, serum albumin, serum bilirubin and prothrombintime, used to determine liver function/dysfunction and injury [10, 11]. The functionality of the liver is determined with the albumin test while the integrity of the liver is determined with the transferases test. The gamma-glutamyltransferase and alkaline phosphatase tests are also used to determine conditions connected to the biliary tract [12, 13].Kidney function tests are simple blood or urine tests that determine kidney function/dysfunction and injury. The key kidney functions are to excrete metabolic wastes, produce calcitriol and erythropoietin, and maintain balance of water, pH, and electrolyte [14]. The following are common parameters assessed during renal function tests: serum urea, serum uric acid, total protein, serum albumin, and serum electrolytes; Na, K, Cl, phosphate, and calcium **[**15]. Data on the correlation between indoor air pollution in chemical stores and liver and kidney toxicity in storekeepers are still emerging and very needful too. Therefore the primary aim of the research work reported herein was to determine whether or not there is hepatoxicity and nephrotoxicity in storekeepers of chemical stores at Ariaria International Market Aba, Abia State, Nigeria resulting from their occupation as storekeepers.

MATERIALS AND METHODS

Study area and subjects

This study was carried out at the section of the Ariaria international market, Aba Abia State Nigeria, where chemicals and hospital equipment are sold. It is situated within 05^o 06' 42.8" N and 07^o 20' 04.7" E. The chemical stores have no windows but only one door for each. The Ariaria opens for business for eleven hours (6a.m. to 5p.m.) daily except on Sundays. This study was carried out between September 2 and November 30. 2021. The subjects were twenty storekeepers; 18 to 55 years of age, selected from 4 selected chemical stores of 4 subjects in. However, the storekeepers who have been in the job for three years or more were selected while alcoholics and those who have smoked before were not selected for the study. Four male storekeepers of garment stores about 1km from the chemical stores of the same market were used as control subjects (Table 1). A written consent was obtained from the storekeepers used in the study, while the ethical approval was given by the research and publications unit of Abia State University Uturu Nigeria.

Table 1. Features of Subjects Used in the Study.

Subjects	Chemical storekeepers	Garment storekeepers (controls)
Total number	I6	4
No. of subjects per store	4	4
Male	4	4
Female	0	0
Mean age (years)	37±16	45±10
Smokers	0	0
Former smokers	0	0
No. of yrs. spent as storekeeper	≥3	≥3

Collection of blood samples

Samples of blood were collected from the veins of subjects and transferred into clean tubes. A portion of the clotted blood was centrifuged at 2000 rpm for 10 minutes. The serum obtained was used for liver and kidney function tests while whole blood was used for the determination of heavy metals since toxic heavy metals bond preferably on red blood cells [16].

Heavy metals assay in the particulates and blood samples

Arsenic (As), lead (Pb), cadmium (Cd), cobalt (Co), and chromium (Cr) were determined from the particulates inside the stores as described by Madu *et al*. [17].The sampling was done by exposing filter papers at a height of about 1.5m from the ground inside the stores for 8hours. The particulates deposited on the filter paper were digested using a mixture of 3% nitric acid and 8% hydrochloric acid. The digest was then evaporated and cooled at 27^{o}C, then dissolved in 11ml of deionized water. The wet acid method described by Ahmed et al. [16] was used in blood sample digestion. Exactly 10ml of freshly prepared 65% trinitrate (V) acid was added into a beaker containing 1.0ml of whole blood and stood for 10 minutes. The beaker was covered with a watch glass and the content was digested for 1 hour and 30 minutes at 65°C. Exactly 2ml of the trinitrate (V) acid was added again to the digest while heating on a hot plate at 80^{o}C to obtain a clear digested solution. The excess trinitrate (V) acid was evaporated, the digest was cooled and 0.1ml of trinitrate (V) acid was added to it. It was then transferred into a 50.0ml volumetric flask and added up to the mark with distilled water. The resultant digested solutions from particulate matter and blood samples were used for the determination of the heavy metals using an atomic absorption spectrophotometer (AAS) UNICAM 939 model.

Measurement of ambient indoor particulates

Particulate matter (PM_1, $PM_{2.5}$, PM_4, PM_7, PM_{10} and total suspended particulate matter; TSPM) was measured as described by Madu et al. [17]. The measurement of particulates was carried out in the morning (8am-11am), afternoon (12pm-2pm) and evening (3:30pm-5pm) at both test and control stores with an Aerocet (531 model) analyzer at a height of 1.5 meters from the floor of the stores.

Renal function tests

The renal function parameters measured are urea, creatinine, sodium ion, potassium ion, bicarbonate ion and, chloride. Serum urea was determined by enzymatic method using the Agappe diagnostic Switzerland test kit. Three test tubes were labeled; blank, standard and sample while 1000µL of working (enzyme) reagent was added to each of the tubes. Exactly 10µL of standard was added to the test tube labeled standard, and 10µL of serum from the subjects was added to the test tube labeled sample. Each of the test tubes was mixed and incubated for 5minutes at 37°C. Then 1000µL of deionized water was added to each of the test tubes and mixed well. The absorbance of the sample and the standard against the reagent blank was determined with a spectrophotometer at 600 nm. The concentration of urea in mg dL^{-1} was calculated using the formula:

$$\text{Urea Concentration (mg dL}^{-1}\text{)} = \text{Absorbance of sample} \times 40 / \text{Absorbance of standard}$$

Where 40 is the standard concentration in mg dL^{-1}. The concentration in $mgdL^{-1}$is converted to mmol L^{-1} (SI unit of Urea) by multiplying the value by 0.1665.

Creatinine concentration was also measured by enzymatic method using the Agappe diagnostic Switzerland test kit. Exactly 450µL of reagent 1(R1) was added to each of the test tubes labeled blank, standard, and sample. Exactly 10µL of the standard was added to the test tube labeled blank while 10µL of serum from the subjects was added to the test tube labeled sample. Each of the test tubes is mixed and incubated for 5 minutes at 37°C. This was followed by the addition of 150µL of reagent 2(R2) into each of the test tubes which were thereafter mixed separately and incubated again at 37°C for 5 minutes. The absorbance of the sample and standard against the reagent blank was measured using a spectrophotometer at 600nm. The concentration of creatinine was calculated using the formula:

Creatinine concentration (mg dL^{-1}) = Absorbance of sample × 2 / Absorbance of standard

Where 2 is the standard concentration in mg dL^{-1}. The concentration in mg $dL^{-1}$is converted to μmol L^{-1} (SI unit of creatinine) by multiplying the value with 88.40

Sodium ion was determined in the serum of subjects by colorimetric method using Teco diagnostic, USA test kit. Exactly 1.0 ml of filtrate reagent was added to each of the four test tubes labeled blank, standard, control and sample. Exactly 50μL of serum from subjects was added to each of the test tubes, and distilled was water added to the blank. The tubes were vigorously shaken and separately mixed continuously for 3 minutes. They were then centrifuged for 10 minutes at 1500G and the supernatant fluids were carefully taken. Fresh test tubes were labeled as previously and 1.0ml of acid reagent was added to each of the test tubes. Exactly 50μl of each supernatant and color developer were separately added to each of the test tubes and mixed. The absorbance of all the tubes was measured with a spectrophotometer at 550nm. The concentration of sodium ion in mEq L^{-1} was calculated using the formula:

Sodium ion Concentration (mEq L^{-1}) = Abs. of Blank – Abs. of sample× 150 / Abs. of Blank – Abs. of standard

Where 150 is the concentration of sodium standard in mEq L^{-1} while Abs. means absorbance. However, 1 mEq L^{-1} = 1 mmol L^{-1}.

Concentration of potassium ions in the serum of subjects was measured by colorimetric method using Teco diagnostic, USA test kit. Exactly 1.0ml of potassium reagent was introduced into each of the test tubes labeled standard, blank and sample. Then 10μL of each of the standard, distilled water and sample (serum) were added into their respective test tubes. The test tubes were separately mixed and allowed to stand for 3 minutes at room temperature. The absorbance of the test tubes was measured at 500nm with a spectrophotometer. The concentration of potassium ion in mEq L^{-1} was calculated using the formula:

Potassium ion concentration (mEq L^{-1}) = Absorbance of sample × 4 / Absorbance of standard

Where 4 is the concentration of potassium standard in mEq L^{-1}.

The concentration of serum bicarbonate is determined using DiaSys diagnostic systems GmbH Germany, test kit. Three test tubes were labeled; blank, standard, and sample while 1000μL of reagent was added to each of the tubes. Exactly 10μL of standard was added to the test tube labeled standard and 10μL of serum from the subjects was added to the test tube labeled sample. Each of the test tubes was mixed and incubated for 5minutes at 37°C. Then 1000μL of distilled water was added to each of the test tubes and mixed well. The absorbance after exactly 2 minutes (A_1) and absorbance after exactly 10 minutes (A_2) of the sample and the standard against the reagent blank were measured at 405nm using a spectrophotometer.

Change in absorbance (ΔA) = $A_2 – A_1$

The concentration of bicarbonate in mmol L^{-1} was calculated using the formula:

Bicarbonate Concentration (mmol L^{-1}) = ΔA of sample × 0.6 / ΔA of standard

Where 0.6 is the concentration of bicarbonate standard in mmol L^{-1}

Chloride concentration is determined by colorimetric method using Teco diagnostic USA, test kit. Exactly 1.5ml of chloride reagent was added into each of the three test tubes labeled blank, standard, and sample. Then 10μL of each of the standard and sample (serum) was added to their respective test tubes and each tube was mixed. They were incubated for 5 minutes at 37^{o}C. The absorbance of the sample and standard against the reagent blank was determined at 480 nm with a spectrophotometer. The concentration of chloride in mEq L^{-1} was calculated using the formula:

Chloride Concentration (mEq L^{-1}) = Absorbance of sample × 100 / Absorbance of standard

Where 100 is the concentration of chloride standard in mEq L^{-1}.

Liver function tests

The liver function parameters measured are total bilirubin, direct bilirubin, aspartate aminotransferase

(AST), alanineaminotransferase (ALT), alkaline phosphatase (ALP), total protein, and albumin. They were all measured using their respective test kits manufactured by Agappe Diagnostics, Switzerland. The procedures were as described in the leaflet of the test kits.

Statistical analysis

The results were analyzed using one-way Analysis of Variance (ANOVA) and the means were separated by Least Significant Difference at a 5% level of significance with the Statistical Package for Social Sciences (SPSS) version 22.

RESULTS

The concentrations (ppm) of heavy metals in the ambient air of the chemical stores are presented in Figure 1. The concentration of cobalt (Co) was highest in store 1 with a value of 0.87±0.14 and lowest in store 4 with a value of 0.19±0.01. These concentrations were significantly higher ($p<0.05$) than the control values and higher than the NESREA standard value of 0.10. Chromium (Cr) recorded the highest concentration (0.95±0.05) in store 1 and the least (0.09±0.01) in store 4. The concentrations were significantly higher ($p<0.05$) than the control and higher than the NESREA standard value of 0.05. The concentration of arsenic was highest (1.11±0.07) in store 2 and lowest (0.82±0.02) in store 4. Concentrations of arsenic in all the stores were statistically higher ($p<0.05$) than the control and higher than the NESREA standard value of 0.75. Figure 1 also shows that the value of lead (Pb) was highest (0.09±0.01) in store 1 and least (0.05±0.01) in store 3 the concentrations were higher ($p<0.05$) than the control value. The concentration of Pb in store 4 was lower than the NESREA standard value. On the other hand, cadmium (Cd) concentration was highest (0.08±0.01) in store 1 and lowest (0.04±0.01) in store 3. However, the control store had no cadmium detected in its indoor air. Concentrations of cadmium in other stores were higher than the NESREA standard value of 0.05 except store 3. Results represent the mean of triplicate results obtained. NESREA = Nigerian Environmental Standard and Regulation Enforcement Agency; Stores 1, 2, 3, 4 = different chemical stores; control = Garment store. Levels (μg m^{-3}) of indoor air particulate matter in chemical stores at Ariaria international market are shown in Figure 2. The value of PM_1 was highest (1.60±0.10) in store 1 and lowest (0.90±0.05) in store 3. The concentrations were significantly higher ($p<0.05$) than the control value (0.20±0.04) and higher than the WHO standard value of 0.25 μgm^{-3}. Concentrations of $PM_{2.5}$ were highest (3.26±0.05) in store 2 and least (0.70±0.11) in store 4. These concentrations were significantly higher ($p<0.05$) than the control value (0.22±0.02) and below the WHO standard value of 10.00 μg $(m^3)^{-1}$. PM_4 level concentrations were of the highest value (3.98±0.11) in store 2 and lowest (0.80±0.06) in store 4. The values were also significantly higher ($p<0.05$) than the control value of 0.50±0.01. Figure 2 also shows that the level of PM_7 varied from 1.05±0.08 in store 4 to 4.01±1.00 in store 2. These concentrations were statistically higher ($p<0.05$) than that of the control except in store 4. PM_{10}concentrations were higher (4.03±0.50) in store 2 and lowest (1.05±0.02) in store 4 which were statistically higher ($p<0.05$) than the control value (1.05±0.03). Total suspended particulate matter (TSPM) recorded the highest value (4.04±0.30) in store 2 and the lowest value (1.06±0.01) in store 4.

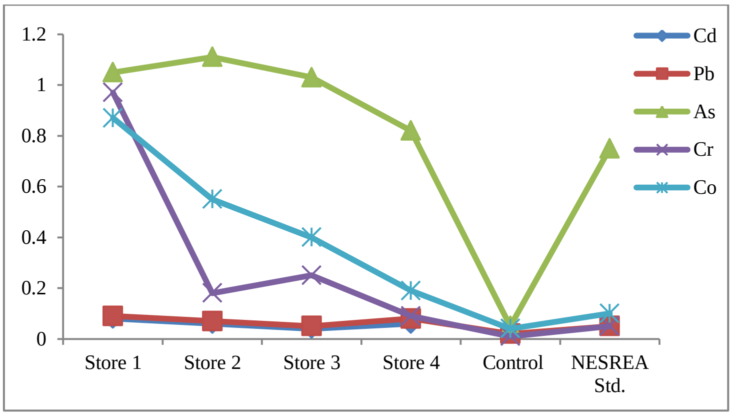

Figure 1. Levels of heavy metals in the ambient air inside the chemical stores at Ariaria Market.

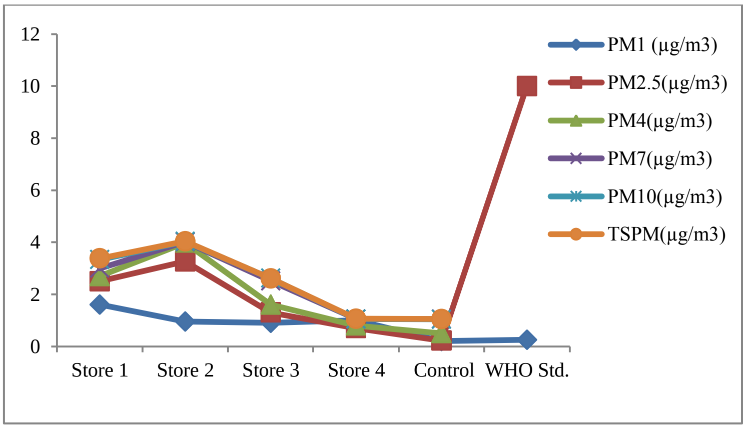

Figure 2. Concentrations of particulates in the ambient air, inside the chemical stores at Ariaria Market

Results represent the mean of triplicate results obtained; Stores 1,2,3,4 = different chemical stores; control = Garment store; PM_I = particulate matter with an aerodynamic diameter of 1µm

$PM_{2.5}$ = particulate matter with an aerodynamic diameter of 2.5µm

PM_4 = particulate matter with an aerodynamic diameter of 4µm

PM_7 = particulate matter with an aerodynamic diameter of 7µm

PM10 = particulate matter with an aerodynamic diameter of 10µm

TSPM = Total suspended particulate matter

Table 2 shows concentrations (µg L^{-1}) of heavy metals in the whole blood samples of chemical storekeepers at Ariaria International market. Concentrations of all the assayed heavy metals varied in the blood samples of chemical storekeepers and were significantly higher ($p<0.05$) than in the control subjects. Lead and arsenic recorded the highest concentrations in all the stores. While the concentrations of lead varied between 4.62±1.01 (in store 2 keepers) and 5.32±0.90 (in store 1 keepers), arsenic concentrations varied between 3.55±0.95 (in store 2 keepers) and 4.92±1.00 (in store 1 keepers). Levels of cadmium were highest (0.19±0.03) in store 1 keepers and lowest (0.10±0.01) in store 4 keepers. On the other hand, chromium concentrations varied between 0.70±0.08 (in store 4 keepers) and 1.90±0.21 (in store 1 keepers). Cobalt also recorded the highest value (0.88±0.06) in blood samples of store 1 keepers and the lowest value (0.49±0.05) in blood samples of store 4 keepers.

Table 2. Concentrations of Heavy Metals in Whole Blood Samples of Chemical Storekeepers at Ariaria International Market, Aba

Heavy metals (μg L^{-1})	Control	SK 1	SK 2	SK 3	SK 4
Cd	0.04±0.01[a]	0.19±0.09[b]	0.13±0.06[c]	0.15±0.06[d]	0.10±0.01[e]
Pb	1.76±0.12[a]	5.32±1.05[b]	4.62±1.26[c]	4.74±0.98[c]	5.01±0.55[d]
As	2.25±0.51[a]	4.92±0.91[b]	3.55±0.94[c]	4.01±1.37[d]	3.62±0.91[c]
Cr	1.00±0.05[a]	1.90±0.84[b]	1.26±0.07[c]	1.35±0.99[d]	0.70±0.56[e]
Co	0.44±0.06[a]	0.88±0.09[b]	0.60±0.04[c]	0.64±0.05[c]	0.49±0.07[d]

Values in the table are means ± standard deviation of quadruplicates values. Figures in the same row having the same letters are statistically significant ($p<0.05$); SK 1 = Storekeepers in chemical store 1; SK 2 = Storekeepers in chemical store 2; SK 3 = Storekeepers in chemical store 3; SK 4 = Storekeepers in chemical store 4; Control = storekeepers of a garment store.

The results of the renal function tests are presented in Table 3. It can be seen that storekeepers in store 1recorded the highest value (8.69±2.64mmol L^{-1}) of serumurea while the least value (7.59±2.22mmol L^{-1}) was recorded in the serum of store 2 keepers. All the values from the chemical storekeepers were statistically higher ($p<0.05$) than that of the control (5.03±1.02). Serum creatinine concentrations varied from 123.76±15.05μmol L^{-1} in store 3 keepers to 150.28±20.00μmol L^{-1} in store 4 keepers. The concentrations were significantly higher ($p<0.05$) than those of the control subjects (106.08±18.62μmol L^{-1}).On the other hand, sodium ion (Na^+) concentrations were least in store 1 keepers (148.00±10.66mmol L^{-1}) and highest in store 4 keepers with a value of 178.20±20.67mmol L^{-1}. However, the values in the chemical storekeepers were significantly higher ($p<0.05$) than those of the control subjects (136.00±20.22mmol L^{-1}).Potassium ion (K^+) concentration was lowest in store 1 keepers (4.90±2.15mmol L^{-1}) and highest in store 4 keepers (6.00±1.50mmol L^{-1}). These concentrations were significantly higher ($p<0.05$) than those of the control (3.70±1.00mmol L^{-1}).Serum bicarbonate (HCO_3^-) recorded the highest value (44.30±10.09mmol L^{-1}) in store 1 keepers and the lowest value (35.00±11.25mmol L^{-1}) in store 3 keepers. The values were significantly higher ($p<0.05$) than the control values of 31.25±5.90mmol L^{-1}).The concentrations of chloride (Cl^-) varied from 100.30±10.00mmol L^{-1} in store 3 keepers to 109.50±15.30mmol L^{-1} in store 4 keepers. These values were also significantly higher ($p<0.05$) than the control value of 102.00±18.00mmol L^{-1}.

Table 3. Concentrations of Kidney Function Parameters in Serum of Chemical Storekeepers at Ariaria International Market, Aba.

Parameters	Control	SK 1	SK 2	SK 3	SK 4	Range	Ref.
Urea (mmol L^{-1})	5.03±1.02[a]	8.69±2.64[b]	7.59±2.22[b]	8.34±2.53[c]	8.54±1.90[b]	1.67-8.33	[18]
Creatinine (μmol L^{-1})	106.08±18.62[a]	136.14±22.01[b]	141.44±21.86[c]	123.76±15.05[d]	150.28±20.00[e]	54.81-103.43	[18]
Na^+ (mmol L^{-1})	136.00±20.22[a]	148.00±10.66[b]	156.40±10.56[c]	175.05±17.00[d]	178.20±20.67[e]	135-155	[19]
K^+ (mmol L^{-1})	3.70±1.00[a]	4.90±2.15[b]	5.30±1.75[c]	5.10±1.78[d]	6.00±1.50[e]	3.40-5.30	[19]
HCO_3^- (mmol L^{-1})	31.25±5.90[a]	44.30±10.09[b]	38.40±13.00[c]	35.00±11.25[d]	41.60±12.22[e]	23.00-33.00	[9]
Cl^-(mmol L^{-1})	102.00±18.00[a]	106.00±17.05[b]	106.80±12.25[b]	100.30±10.00[c]	109.50±15.30[d]	98.00- 106.00	[19]

Values in the table are means ± standard deviation of quadruplicates values. Figures in the same row having the same letters are statistically significant ($p<0.05$); SK 1 = Storekeepers in chemical store 1; SK 2 = Storekeepers in chemical store 2; SK 3 = Storekeepers in chemical store 3; SK 4 = Storekeepers in chemical store 4; Control = storekeepers of a garment store.

The liver function test results are presented in Table 4. From the results, the concentrations of total bilirubin (μmol L^{-1}) were highest (22.91±8.21) in store1 keepers and least (15.39±4.00) in store 3 keepers. These values were significantly higher than the control value of 11.97±2.72. The concentrations of direct bilirubin measured in μmol L^{-1} varied from 5.13±1.90 in the serumof store 3 keepers to 11.12±3.12 in store 1 keepers. However, the concentrations of direct bilirubin in chemical store keepers were higher ($p<0.05$) than those in the control subjects with a value of 3.42±0.92.Aspartate aminotransferase (AST) recorded the highest value (0.85±0.10µKat L^{-1}) in the serum of store 1 keepers and the least (0.79±0.90µKat L^{-1}) in store 2 keepers.These values were significantly ($p<0.05$) higher than the control value of 0.34±0.08 µKat L^{-1}.Alanine aminotransferase (ALT) recorded the highest concentration (1.02±0.11µKat L^{-1}) in the serum of store 1 keepers and the least (0.83±0.21µKat L^{-1}) in store 3 keepers. These concentrations were also significantly higher ($p<0.05$) than the control value of 0.53±0.12µKat L^{-1}).The concentrations of alkaline phosphatase (ALP) measured in µKat L^{-1} ranged from 2.56±0.98 in serum of store 2 keepers to 5.24±1.15 in store 4 keepers. The concentrations of ALP in the serum of chemical storekeepers at the Ariaria international market were significantly ($p<0.05$) higher than the control values (1.66±0.52). Total protein (g L^{-1}) recorded the lowest value (62.00±14.45) in the serum of store 3 keepers and the highest value (75.00±15.80) in store 4 keepers. These values were also statistically lower ($p<0.05$) than the control value of 80.00±11.20. Table 4 also shows that concentrations of serum albumin in g L^{-1} varied from 26.00±5.60 in store 2 keepers to 38.00±10.76 in store 4 keepers and were significantly ($p<0.05$) lower than the control value (39.00±10.55).

Table 4. Concentrations of Liver Function Parameters in Serum of Chemical Storekeepers atAriaria International Market, Aba

Parameters	Control	SK 1	SK 2	SK 3	SK 4	Range	Ref.
Total Bilirubin (µmol L^{-1})	$11.92±2.72^a$	$22.91±8.21^b$	$20.52±12.60^c$	$15.39±4.00^d$	$22.40±11.09^b$	0.00-20.52	
Direct Bilirubin (µmol L^{-1})	$3.42±0.92^a$	$11.12±3.12^b$	$9.41±I.03^c$	$5.13±1.90^d$	$7.70±2.24^e$	0.00-6.84	
AST(µKat L^{-1})	$0.34±0.08^a$	$0.85±0.10^b$	$0.79±0.90^c$	$0.82±0.20^d$	$0.83±0.21^d$	0.00-0.78	
ALT (µKat L^{-1})	$0.53±0.12^a$	$1.02±0.11^b$	$0.91±0.11^c$	$0.83±0.10^d$	$0.86±0.11^e$	0.00-0.83	[18]
ALP (µKat L^{-1})	$1.66±0.52^a$	$2.64±0.96^b$	$2.56±0.98^c$	$2.60±0.90^b$	$5.24±1.15^d$	1.36-5.20	
Total Protein (g L^{-1})	$80.00±11.20^a$	$67.00±15.84^b$	$70.00±10.01^c$	$62.00±14.45^d$	$75.00±15.80^e$	60.00-80.00	
Albumin (g L^{-1})	$39.00±10.55^a$	$30.10±9.00^b$	$26.00±5.60^c$	$35.00±12.60^d$	$38.00±10.76^e$	35.00-52.00	

Values in the table are means ± standard deviation of quadruplicates values. Figures in the same row having the same letters are statistically significant ($p<0.05$); SK 1 = Storekeepers in chemical store 1; SK 2 = Storekeepers in chemical store 2; SK 3 = Storekeepers in chemical store 3; SK 4 = Storekeepers in chemical store 4; Control = storekeepers of a garment store; AST = Aspartate aminotransferase; ALT = Alanine aminotransferase; ALP = Alkaline phosphatase

DISCUSSION

Heavy metals are metallic elements that have an atomic density greater than $5gm^{-3}$ and are characteristically persistent, bioaccumulative, and toxic. They may be present in the air, soil, and natural water bodies [20].Results of the present study show that the concentrations of all the assayed heavy metals in the ambient air of the chemical stores were significantly higher than in the garment stores (control). This could be a result of emissions of these heavy metals from their salts which are contained in the chemical stores. These salts might have found their way into the indoor air through the activities of the storekeepers which involve offloading, repackaging, rebottling, and improper storage of the salts. The elevated levels of these heavy metals in the indoor air of the chemical stores resulted in their increased levels in the blood samples of the storekeepers. This is so, as the storekeepers might have inhaled increased concentrations of the heavy metals from the indoor air of the stores or they have been eating foods contaminated with deposits of heavy metals from within the chemical stores. Lead and arsenic are more bioaccumulative [21, 22]. This may explain why they were of the highest concentrations in the blood samples of the chemical storekeepers. Elevated concentrations of heavy metals in the blood impair kidney and liver functions [23]. Cadmium mimics the behavior and function of some useful metals and therefore competes with them for binding sites in enzymes and other proteins. Cadmium (Cd) binds with metallothionein (MT) to form a Cd-MT complex. A high concentration of free cadmium exerts its toxicity on the kidney when it dissociates from metallothionein. The cadmium-metallothionein complex is not toxic to the kidney. However, MT separates from the Cd-MT complex after glomerular filtration of the complex. This releases free cadmium in the kidney which causes kidney dysfunction [24]. The same mechanism is utilized for cadmium toxicity in the liver. High concentrations of lead cause increased activities of AST, ALP, and ALT in experimental animals [25]. In the liver, Arsenic can cause the generation of reactive oxygen species (ROS) and cytochrome C release which promotes the hepatotoxic effect of arsenic [26]. Chromium also produces ROS which is mainly responsible for their toxicity in the kidney and liver. In the kidney and liver, cobalt interacts with sulfhydryl groups of thiol enzymes to impair their activities. This interaction can cause the formation of ROS, severe mitochondrial damage, and malfunction of the tricarboxylic acid (TCA) cycle [27].

Particulate matter is a mixture of droplets and solids in the air that contains various substances such as acids, metals, dust, organic compounds, and soils [8]. It can cause kidney [28] and liver [29] dysfunctions. Our findings, reported herein, indicate that there were increased particulate matter concentrations in all the chemical stores studied. This could be due to the emission of particulates from the chemicals during the offloading, packing, and handling of the chemicals inside the stores or from dust within the stores. The raised particulate matter concentration could also be because the stores are poorly ventilated – without windows and therefore most of the particulates were trapped in them.

The primary kidney functions are to excrete metabolic wastes, produce calcitriol, and erythropoietin and maintain balance of water, pH, and electrolyte [14]. These functions can be impaired when there is the presence of kidney disease or injury. Heavy metals and particulate matter have been implicated in kidney dysfunction as discussed earlier in this section. The concentrations of the kidney function parameters measured in this study suggest that the chemical storekeepers at Ariaria International Market might have mild kidney dysfunction. The concentrations of serum urea of the chemical storekeepers were significantly higher ($p<0.05$) than the control and apart from storekeepers in store 2, urea concentrations of the chemical storekeepers were higher than the reference value of 1.67-8.33mmol L^{-1}.Urea is the end product of the metabolism of protein which is cleared from the blood through the kidney. An Elevated concentration of serum urea is an indication of various renal disorders [30] such as glomerular nephritis, chronic nephritis, and nephritic syndrome. Nevertheless, elevated levels of serum urea could mean dehydration, increased breakdown of protein, diarrhea, and vomiting. Creatinine is a waste product produced from phosphocreatinine in the muscles. Our results show that concentrations of serum creatinine in the chemical storekeepers increased significantly ($p<0.05$) and were also higher than the reference value of 54.81-103.43 µmol L^{-1}. Elevated serum creatinine also indicates kidney dysfunction [14]. Sodium ion is a key cation in the extracellular fluid which is pivotal to the regulation of normal distribution of water and osmotic pressure in fluid compartments. Elevated serum sodium concentrations as determined in the present study could mean severe dehydration caused by loss of water, excess sodium salt treatment, and Cushing’s syndrome. Potassium ion on the other hand is the key cation in the intracellular fluid. Elevated serum potassium concentration determined in our study is associated with urinary obstruction, oliguria, and anuria. Bicarbonate and chloride are the major anions within both intracellular and extracellular fluids. Bicarbonate plays a key role in the regulation of acid-base status in the body while chloride ion controls the distribution of water between the tissues by maintaining normal anion and cation balance and osmotic pressure of the extracellular and intracellular fluids. We found in the present study that concentrations of serum bicarbonate and chloride in the chemical storekeepers at Ariaria were individually higher than the control and higher than the respective reference ranges. However, elevated concentrations of serum bicarbonate may indicate metabolic alkalosis or compensated respiratory acidosis. Madu et al. [8] had earlier found that the pH of the exhaled breath condensate of these chemical storekeepers was slightly acidic. On the other hand, elevated concentrations of serum chloride may indicate dehydration.

The results of the liver function test in the present study also indicate that the chemical storekeepers could be suffering from mild liver dysfunction. This follows the fact that concentrations of serum bilirubin, and liver enzymes were elevated while total protein and albumin concentrations were decreased in the majority of the chemical storekeepers. Bilirubin is a product of the breakdown of erythrocytes in the liver, bone marrow and spleen. Elevated concentrations are found in obstruction of the biliary tract, chemical-induced reactions, cirrhosis, hepatitis, and hemolytic jaundice. Increased concentrations of serum AST, ALT, and ALP are found in various types of liver diseases [31]. Decreased concentrations of serum total protein and albumin are indicative of chronic liver diseases such as nephritic syndrome and cirrhosis [11].

This study has some possible limitations which may be addressed in future research. We regret that only four chemical stores and sixteen chemical storekeepers were used in this study. This decreased the sample size which might have slightly increased the margin of error. Four chemical stores and sixteen chemical storekeepers were used because of the scarcity of the stores that have storekeepers with the inclusion criteria. Again, other conditions apart from liver disorders may be responsible for abnormal results in liver function tests. Therefore in future studies, other methods together with the liver function tests should be used to determine liver disease.

CONCLUSIONS

We found that there were strong indications of renal and hepato-toxicities in the chemical storekeepers at Ariaria international market resulting from their exposure to elevated concentrations of toxic heavy metals and particulates. Some of the possible causes of this development in our observation are unethical practices by the chemical storekeepers which include careless and improper storage of the chemicals in the stores, off-loading, repackaging, and rebottling of the chemicals inside the stores. The poor ventilation in the chemical stores also contributed to their pollution status. To ensure workplace safety and health, we recommend that the chemical storekeepers desist from repackaging, off-loading, and rebottling of chemicals inside the stores. They should also maintain proper hygiene within the stores and consider sitting outside the stores when they are not attending to customers. The government of Abia State, Nigeria, may consider reconstruction of the chemical stores in the Ariaria International Market to have windows to ensure good ventilation in the stores.

Conflict of interests

The authors declare no competing interests.

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