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The levels of inflammatory markers and oxidative stress in individuals occupationally exposed to municipal solid waste in Ogun State, South West Nigeria

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Abstract

Airway inflammation and related respiratory complaints are common symptoms among waste management workers (WMWs). This study investigated the relationship between exposure to municipal solid waste (MSW) and the levels of inflammatory markers and oxidative stress among WMW of Ogun State, South West Nigeria. A total of 280 subjects consisting of 180 WMW and 100 controls were recruited. Ten millilitres of blood were collected from antecubital vein of the subjects for analysis. Results reveal that exposure to MSW is associated with systemic inflammation and oxidative stress. Significant ($p < 0.001$) elevation of ceruloplasmin (Cp) and C-reactive protein was associated with marked decreases in superoxide dismutase ($p < 0.01$), catalase ($p < 0.001$), and glutathione ($p < 0.05$) and significant ($p < 0.001$) increases in malondialdehyde (MDA) and uric acid when compared with control. Haematological disorders include significant ($p < 0.05$) decreases in haemoglobin, packed cell volume, and mean corpuscular volume and significant ($p < 0.01$) increase in total leucocyte count. Apart from decreased albumin ($p < 0.05$) and elevated aspartate aminotransferase ($p < 0.05$) activity observed in WMW, other markers of hepatic (alanine aminotransferase, alkaline phosphatase, total cholesterol and triglycerides) and renal (urea and creatinine) functions did not change significantly ($p > 0.05$) when compared with the control. A positive correlation between leucocytes ($r = 0.195$, $p < 0.01$), Cp ($r = 0.210$, $p < 0.01$) and job duration and between Cp and MDA ($r = 0.200$, $p < 0.01$) and Cp and leucocytes ($r = 0.260$, $p < 0.001$) were observed in WMW. Overall, exposure to MSW predisposes to systemic inflammation and oxidative stress and Cp may be a useful biomarker for monitoring health status of Nigerian WMWs.

Keywords

Systemic inflammation, oxidative stress, municipal solid wastes, health effect, occupational exposure

Introduction

Waste is a complex mixture of different substances that serve as breeding ground for bacteria and fungi, some of which are intrinsically hazardous to health (Rushton, 2003). Over the past few decades, the potential health effects of waste and the consequences of managing it have been the subject of a vast body of research in both the developed and developing countries of the world. Waste collection has become a necessary activity all around the world and some people do it as a means of livelihood. In Nigeria, infectious medical wastes, toxic industrial solid wastes and

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domestic wastes are disposed together and over 25 million tonnes of this municipal solid waste (MSW) are generated annually (Ogwueleka, 2009). Individuals involved in the collection, transport, transfer and management of this waste may be exposed to elevated concentrations of biological aerosols (Ray et al., 2009). Occupational biorisks are those derived from the presence of micro- and macroorganisms (Nwanta et al., 2010) and/or substances generated by them in occupational environment. In comparison to the effects caused by chemical and physical agents, those of biological origin are less known and not so well defined. However, they can act as infectious, allergenic, toxic and carcinogenic agents in humans (Schlosser and Huyard, 2008). The MSW contains huge amounts of organic materials which can be of vegetal, microbiological or animal origin. Biological degradation which takes place during processing of these wastes further increases the avenue for exposure to organic dusts (Kuijer et al., 2010). The individuals who handle MSW can also be exposed to parasitic protozoa and other infectious microorganisms that produce allergenic endotoxins (Nwanta et al., 2010). In addition to this, workers of MSW composting facilities are also exposed to organic dusts that are the cause of several general occupationally related health problems. Among these are typhoid fever, acute pulmonary inflammation, hypersensitive pneumonitis, occupational asthma, chronic bronchitis and related respiratory complaints (Alvarado-Esquivel et al., 2008; Athanasiou et al., 2010; Domingo and Nadal, 2009; Kuijer et al., 2010). Significant association between inflammation of upper airways with nasal lavage concentration of interleukin-8 and microbial components of endotoxin and 1,3-β-D-glucan in waste disposal areas has been demonstrated (Gruner et al., 1999; Ivens et al., 1999; Wouters et al., 2002). There is now a large body of data that suggests that systemic inflammation may be the "missing link" between airway dysfunction and the extrapulmonary manifestations of chronic obstructive pulmonary disease (Gan et al., 2004; Sin and Man, 2006). Some studies have related the cause of inflammation in respiratory system to higher levels of neutrophil counts and production of proinflammatory cytokines (Heldal et al., 2003; Kalahasthi et al., 2010). Phagocytic cells (such as neutrophils, macrophages and monocytes) are part of the innate immune system and are known to play crucial role during inflammatory response. Upon activation, they produce toxic substances that destroy and remove bacteria, cells infected with bacteria and apoptotic/necrotic cells (Paul, 2003). These toxic substances, which include proteolytic enzymes, nitric oxide and reactive oxygen species (Roitt and Delves, 2001), act on nearby cells and pathogenic agents by damaging cell walls, proteins, lipids and genetic material. Thus, inflammation and the phagocytic cells associated with inflammation are a major source of oxidative stress to the biological system (Yeo et al., 2005). Data on the possible harmful effects and the overall health hazards that MSW pose both to the handlers and to the entire environment are still very scanty. So far, the biochemical mechanisms and alterations responsible for the reported adverse health effects associated with occupational exposure to MSW have not been clearly elucidated. In this study, we monitored some important plasma biomarkers of inflammation and oxidative stress with the view to identifying relevant biomonitoring tools that may be useful in assessing the health status of waste management workers (WMWs) and possible hazards associated with the disposal of wastes in Nigeria.

Materials and methods

Fieldwork was performed between March and November 2010. Participants were selected by purposive sampling in line with previous study by Mbeng (2009) and Mbeng et al. (2009). The study groups included nonwaste healthy male and female (0.9:1.1) workers ($n = 100$) and male and female (0.9:1.1) MSW management workers ($n = 180$) from five private waste companies in Ijebu-Ode, Ago-Iwoye and Sagamu of Ogun State, South West of Nigeria. Subjects in both study groups were between 20 and 54 years of age. The MSW management workers were categorized into three major groups according to the job duration. Group I were those who had 6 months–2 years of experience; group II were those with 2–4 years of experience while group III were those who had been on the job for more than 4 years. In order to ensure that individuals with underlying conditions that may influence results of the present study were not recruited, exclusion criteria were set, among others, to include presence of conditions (such as diabetes, asthma, hypertension and malaria) with underlying inflammatory or immune responses and the use of drugs that interfere with inflammatory and/or immune functions (Savoia and Sciffrin, 2006; Shoelson et al., 2006; Thevenon et al., 2010; Wardlaw et al., 2002). Also, individuals with any visible wound or lesion that may predispose to infection and/or inflammation were not recruited. The medical ethics committee of Olabisi Onabanjo University Teaching Hospital (OOUTH)/Obafemi Awolowo College of Health Sciences of the Olabisi Onabanjo University approved the study (ethical approval number OOUTH/DA.226/T/2), and participants gave informed written consent in accordance with Helsinki Declaration of 1964 as amended in 1983 (World Medical Organization, 1996). Ten millilitres of blood sample were collected from the antecubital vein of the subjects for analysis.

Evaluation of systemic inflammation

Ceruloplasmin (Cp) was measured from its oxidase activity in plasma using *o*-dianisidine dihydrochloride as described by Schoslnsky et al. (1974). Albumin was determined using the bromocresol green method as described by Doumas et al. (1971). C-reactive protein (CRP) was determined according to the method of Eda et al. (1999).

Assay of antioxidant enzymes

Catalase (CAT) activity was determined according to the spectrophotometric method described by Clairborne (1995). The assay was based on the ability of CAT to induce the disappearance of H_2O_2. Superoxide dismutase (SOD) activity was determined based on the ability of SOD to inhibit the spontaneous oxidation of adrenaline to adrenochrome as described by Magwere et al. (1997).

Determination of malondialdehyde, reduced glutathione and uric acid

Lipid peroxidation was estimated spectrophotometrically by the thiobarbituric acid reactive substance (TBARS) method as described by Varshney and Kale (1990) and malondialdehyde (MDA) was quantified using a molar extinction coefficient of 1.56×10^5 M^{-1} cm^{-1} (Buege and Aust, 1978). Reduced glutathione (GSH) level was estimated at 412 nm according to the method of Beutler et al. (1963), while uric acid (UA) was determined based on the principles described by Fossati et al. (1980) using commercial kit obtained from Randox Laboratories Ltd (Crumlin, UK).

Determination of haematological parameters

All haematological parameters were measured using fully automated haematology analyzer MINDRAY BC 3000 PLUS (Shenzhen Mindray Bio-Medical Electronics Co. Ltd., China).

Assessment of hepatic function

Liver function was assessed by measuring the activities of aspartate aminotransferase (AST), alanine aminotransferase (ALT) and alkaline phosphatase (ALP) in plasma. AST and ALT activities were determined according to the principle described by Reitman and Frankel (1957), while the ALP activity was carried out according to the method described by Roy (1970). Total cholesterol (TC) and triglyceride (TG) concentrations were estimated by the principle described by Trinder (1969) using commercial kits obtained from Randox Laboratories Ltd (Crumlin, UK).

Assessment of renal function

Renal function test was carried out by measuring blood urea nitrogen (BUN) and plasma creatinine (pCr) concentrations. BUN was determined based on the principle of condensation of diacetyl with urea (Fearon, 1939), while pCr was determined according to the method described by Jaffe et al. (1987) using commercial kits purchased from Randox Laboratories Ltd (UK).

Statistical analysis

Results are presented as mean $\pm$ standard deviation. Data are analyzed using Statistical Package for the Social Sciences (SPSS) version 16.0. Comparison between waste workers and control was performed using Student's t test for unpaired data and Pearson's correlation coefficient. The statistical significance was set at $p < 0.05$.

Results

Job categorization of MSW workers

The average duration of employment for the MSW workers was 4.0 ± 1.2 years. The cumulative relative frequency curve relating percentage of MSW workers and their job duration indicates that 50% of the WMWs studied had worked for about 3.6 years in the facilities (Figure 1).

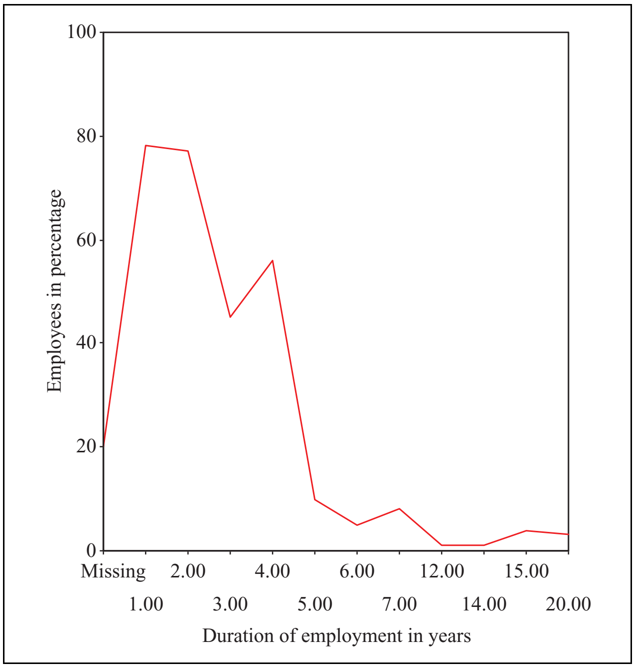

Figure 1. Cumulative relative frequency of job duration of waste management workers.

Systemic inflammation

Table 1 summarizes the levels of ceruloplasmin oxidase activity, CRP, albumin in plasma of MSW workers and control groups. Cp and CRP levels significantly ($p < 0.001$) increased and albumin levels decreased significantly ($p < 0.05$) in the MSW group when compared with control. Ceruloplasmin oxidase activity and CRP levels of MSW group increased by 17.56% and 38.89%, respectively, while albumin decreased by 4.55% when compared with control.

Haematological parameters

Table 2 shows the haematological parameters of MSW workers and control groups. Haemoglobin, packed cell volume (PCV) and mean corpuscular volume (MCV) decreased significantly ($p < 0.05$), while total leucocyte count significantly increased ($p < 0.01$) in the MSW workers when compared with control. There were no significant ($p > 0.05$) changes between total red blood cell (RBC) count, mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration of MSW workers group and those of the control group. In MSW workers, haemoglobin decreased by 3.96%, RBCs by 1.51%, PCV by 3.50%, MCV and MCH by 2.77% and 2.42%, respectively.

Antioxidant parameters

Table 3 depicts the blood levels of MDA, UA, GSH, as well as the activities of SOD and CAT in MSW workers and control groups. MSW workers exhibited significant ($p < 0.001$) increases in MDA and UA levels together with marked decreases in SOD ($p < 0.001$) and CAT ($p < 0.001$) activities as well as GSH ($p < 0.05$) levels when compared with control. MDA increased by 36.96%, UA by 15.91% while SOD activity decreased by 18.72% and CAT activity by 9.47% and GSH by 12.88%.

Renal and hepatic functions

The effect of exposure to waste on renal function is shown in Figure 2. BUN and pCr concentrations in the MSW workers were not significantly ($p > 0.05$) different from those of the control (Figure 2). Effect on hepatic function in both MSW workers and control subjects is shown in Table 4 and Figure 3. AST activity increased significantly ($p < 0.05$) by 34.30%, while ALT and ALP did not change appreciably ($p > 0.05$) in the MSW workers when compared with control. Similarly, TC and TG concentrations were also not significantly ($p > 0.05$) different between the MSW workers and control (Figure 3). TC increased by 1.35% while TG decreased by 9.85% when compared with controls.

Correlation of job duration and some of the analyzed parameters

Table 5 shows the degree of association between MDA, white blood cell (WBC), Cp and CRP and job duration. Ceruloplasmin oxidase activity ($r = +0.210$; $p < 0.05$) and total leucocyte count ($r = +0.195$; $p < 0.05$) exhibited significant positive correlation, respectively, with job duration. MDA and CRP showed no significant correlation with job duration. Furthermore, significant correlation between Cp and plasma MDA level ($r = 0.200$, $p < 0.01$) and Cp and WBC ($r = 0.260$, $p < 0.001$) were observed in MSW workers but such correlation was not seen in control group.

Discussion

In the last few years, attempts have been made regarding the evaluation of health impact of MSW on workers handling them in Nigeria (Confidence and Eleanya, 2007; Mba, 2004; Oyelola et al., 2009). Several studies have reported high incidence and

Table 1. Levels of biomarkers of systemic inflammation in waste and nonwaste management workers.[a]

Group	CRP (mg/dl)	Cp (U/L)	Alb (g/dl)
MSW workers ($N = 180$)	1.75 ± 0.83[b] (38.89%)[c]	134.24 ± 42.07[b] (17.36%)[c]	3.57 ± 0.45[d] (−4.55%)[c]
Control ($N = 100$)	1.26 ± 0.64	114.38 ± 32.41	3.74 ± 0.45

Cp: ceruloplasmin oxidase activity; CRP: C-reactive protein; Alb: albumin.
[a]Results are expressed as mean ± standard deviation (SD). Values within parentheses represent % change; (+) increase; (−) decrease.
[b]$p < 0.001$ when compared with control group.
[c]Percentage change relative to control group.
[d]$p < 0.05$ when compared with control group.

Table 2. Changes in haematological parameters in waste management workers.[a]

	Subjects	
Parameters	Control ($N = 100$)	MSW workers ($N = 180$)
Hb (g/dl)	13.40 ± 1.50	12.87 ± 1.54[b] (−3.96%)[c]
RBC (cells $\times 10^6/\mu l$)	4.64 ± 0.55	4.57 ± 0.55 (−1.51%)[c]
PCV (%)	38.33 ± 4.13	36.99 ± 4.37[b] (−3.50%)[c]
MCV (fl)	80.88 ± 7.19	78.64 ± 8.31[b] (−2.77%)[c]
MCH (pg)	28.93 ± 2.95	28.23 ± 2.47 (−2.42%)[c]
MCHC (g/dl)	35.81 ± 2.32	35.70 ± 2.34 (0.001%)[c]
WBC (cells $\times 10^3/\mu l$)	5.18 ± 0.98	5.69 ± 1.55[d] (9.85%)[c]

Hb: haemoglobin; PVC: packed cell volume; MCH: mean corpuscular haemoglobin; MCHC: mean corpuscular haemoglobin concentration; MCV: mean corpuscular volume; RBC: total erythrocyte count; WBC: white blood cell count.
[a]Results are expressed as mean ± standard deviation (SD). Values within parentheses represent % change; (+) increase; (−) decrease.
[b]$p < 0.05$ when compared with control group.
[c]Percentage change relative to control group.
[d]$p < 0.01$ when compared with control group.

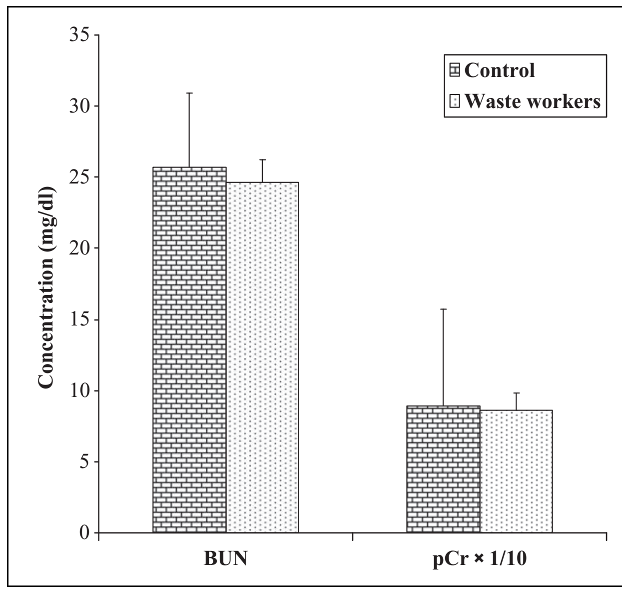

Figure 2. Blood urea nitrogen and plasma creatinine levels of waste management workers. Values are expressed as mean ± standard deviation. BUN: blood urea nitrogen; pCr: plasma creatinine.

increased predisposition to airway inflammation in MSW workers (Athanasiou et al., 2010; Heldal et al., 2003; Ray et al., 2009; Wouters et al., 2002). Depending on whether it is lower or upper airway assessment, the airway inflammation in most cases was assessed either by induced sputum (Heldal et al., 2003; Wouters et al., 2002) or by nasal lavage (Wouters et al., 2002). Both procedures, however, are inflammatory stimuli that may interfere with the results by increasing inflammatory cells and mediators (Holz et al., 1998). In this present study, therefore, we assessed the levels of biomarkers of systemic inflammation and oxidative stress in MSW workers in Ogun State, South West of Nigeria. A preliminary assessment of the inflammatory indices in the various categories of MSW management workers was carried out based on their job duration, and we established significant elevations in the level of these biomarkers when compared with the control subjects (data not shown). Since the cumulative relative frequency curve relating MSW management workers and their job duration indicated that half of the population (50%) of the WMWs fall within the same job duration of about 3.6 years (Figure 1), all the waste workers (180 MSW management workers) who participated in this study were pooled together and compared with the controls (100 nonwaste workers).

In this study, the significant elevation in the level of inflammatory markers observed in MSW management workers suggests progressive inflammatory processes in these subjects. Our result appears to strongly point to the presence of some underlying processes

Table 3. Markers of oxidative stress/antioxidant status of waste management workers.[a]

Subjects	MDA (nmol/ml)	GSH (mg/dl)	UA (mg/dl)	SOD[b]	CAT[c]
MSW workers ($N = 180$)	2.92 ± 1.04^{d} (70.76%)[e]	11.70 ± 3.50^{f} (−13.0%)[e]	6.92 ± 2.27^{d} (15.91%)[e]	5.47 ± 1.25^{f} (−18.72%)[e]	43.11 ± 6.17^{g} (−9.47%)[e]
Control ($N = 100$)	1.71 ± 0.85	13.43 ± 4.93	5.97 ± 1.02	6.73 ± 1.50	47.62 ± 5.19

MDA: malondialdehyde; GSH: glutathione; UA: uric acid; SOD: superoxide dismutase; CAT: catalase.
[a]Results are expressed as mean ± standard deviation (SD). Values within parentheses represent % change; (+) increase; (−) decrease.
[b]Activity expressed as units of enzymes required to inhibit autooxidation of adrenaline to adrenochrome.
[c]Activity expressed as µmol H_2O_2 consumed/min/mg Hb.
[d]$p < 0.001$ when compared with control group.
[e]Percentage change relative to control group.
[f]$p < 0.01$ when compared with control group.
[g]$p < 0.05$ when compared with control group.

Table 4. Liver function test of waste management workers.[a]

Subjects	AST (U/L)	ALT (U/L)	ALP (U/L)
MSW workers ($N = 180$)	22.51 ± 14.71^{b} (34.30%)[c]	10.03 ± 5.50 (2.14%)[c]	17.77 ± 6.46 (−3.69%)[c]
Control ($N = 100$)	16.76 ± 6.64	9.82 ± 3.87	18.45 ± 6.08

ALT: alanine aminotransferase; AST: aspartate aminotransferase; ALP: alkaline phosphatase.
[a]Result expressed as mean ± standard deviation (SD). Values within parentheses represent % change; (+) increase; (−) decrease.
[b]$p < 0.05$ when compared with control group.
[c]Percentage change relative to control group.

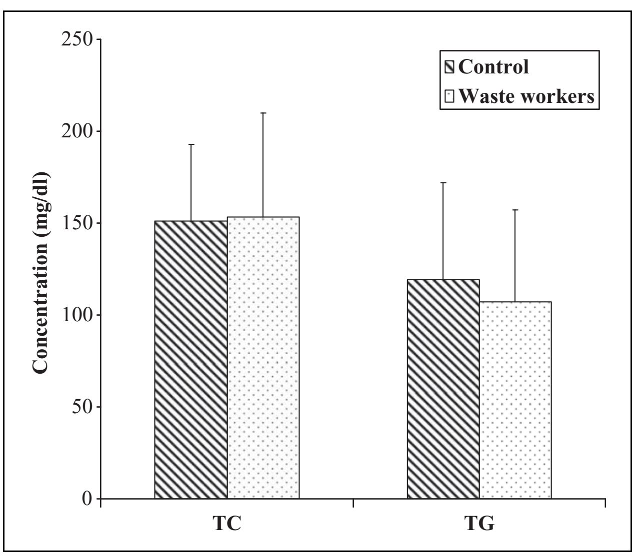

Figure 3. Plasma total cholesterol and triglyceride levels of waste management workers. Values are expressed as mean ± standard deviation. TC: total cholesterol; TG: triglyceride.

related to inflammation and this may be relevant to occupational exposure to solid waste in Nigeria. Waste collection process is usually manual and involves the release of bioaerosol that may cause environmental pollution and severe airway inflammation. Increased proinflammatory cytokines, usually indicated by excess CRP in the blood, are a major underlying cause of systemic inflammation (Verdecchia et al., 2002). Similarly, the prognostic role of Cp in the diagnosis of untreated and recurrent infection and inflammation derives from its primary actions as a transporter of copper, antioxidant and its ferroxidase effect (Natesha et al., 1992). Although plasma CRP was significantly elevated in the MSW management workers when compared with the control subjects, the extent of increase was, however, lower than those previously reported in acute bacterial or viral infections (Fassbender et al., 1991). The change in plasma concentrations of CRP and Cp is similar to those observed by Whicher and Westacott (1992) and suggests the presence of chronic inflammation in the MSW management workers. The significant decrease in plasma albumin concentration further strengthens this argument since albumin (with half-life of approximately 20 days) is known to decrease in chronic liver disease. This observation is important because it describes the overall type of inflammation in this population, since CRP concentration is known to increase by 100- to 1000-fold in

Table 5. Coefficient of correlation between parameters and job duration of waste management workers ($n = 180$).

Parameter/duration	Correlation coefficient (r)				
	MDA	WBC	Cp	CRP	Duration
Duration	0.081	0.195[a]	0.210[a]	−0.094	1.00
MDA	1.00	0.044	0.200[a]	0.012	0.081
WBC	0.044	1.00	0.260[b]	−0.014	0.195[a]
Cp	0.200[a]	0.260[b]	1.00	0.343[b]	0.210[a]
CRP	0.012	−0.014	0.343[b]	1.00	−0.094

MDA: malondialdehyde; WBC: white blood cell count; Cp: ceruloplasmin oxidase activity; CRP: C-reactive protein.
[a] $p < 0.05$.
[b] $p < 0.01$.

acute inflammation, whereas the increase is much less in chronic inflammation (Whicher and Westacott, 1992). Thus, the MSW management workers in the present study could be categorized as undergoing a chronic low-grade inflammatory response to continuous and prolonged exposure to solid waste.

The observed increase in CRP and Cp (typical of chronic inflammation) in this study correlates with the induction of oxidative stress in the MSW management workers. Our results indicate significant elevation of lipid peroxidation in these subjects when compared with control. Environmental pollutants and bioaerosol generated during waste handling have been reported to enhance peroxidative processes and oxidative stress within cells (Liu et al., 2008; Wright and Welbourne, 2002). Elevated levels of the TBARS and MDA reveal peroxidative damage to cell membranes and other lipid-derived macromolecules. The enhanced lipid peroxidation observed in the MSW management workers when compared with control subjects correlates with the decrease in antioxidant defence system in their blood. This is evident in the significant decrease in the enzymic antioxidants—SOD and CAT—as well as the nonenzymic redox sensitive thiol compound, reduced GSH. Our result is in consonance with the findings of Possamai et al. (2009) who detected oxidative stress in the blood of incineration workers of hospital residues. Similar observations were made by Liu et al. (2008) in MSW workers at a bottom ash recovery and fly ash treatment plants. In addition, xanthine oxidase, an enzyme of purine metabolism, is known to catalyze the conversion reactions of hypoxanthine to xanthine and xanthine to UA with the by-product of toxic superoxide radical. In this regard, it is a key enzyme between purine and free radical metabolism (Gulec et al., 2003). Elevated concentration of UA reflects a separate underlying disease process or increased xanthine oxidase activity (Dawson and Walters, 2006). The rise in plasma UA level observed in the MSW management workers in this study, therefore, suggests increased xanthine oxidase activity and superoxide radical production, and this may also have contributed to the inflammatory process and oxidative stress in these subjects.

Data from this study seem to suggest that the presence of oxidative stress in the MSW management workers is related to an underlying chronic inflammatory response to bioaerosol or other harmful components from the waste materials they come in contact with at the dumpsites on a daily basis. The significant increase in WBC count in the MSW management worker when compared with the control subjects also provides a basis for this assertion. Several studies have reported high incidence of respiratory disorders, some of which include pulmonary inflammation, occupational asthma and chronic bronchitis and related respiratory complaints (Athanasiou et al., 2010; Domingo and Nadal, 2009; Kuijer et al., 2010). Some studies have related the cause of inflammation of the respiratory system to higher levels of neutrophil counts and production of proinflammatory cytokines (Heldal et al., 2003). Phagocytic cells are part of the innate immune system and are known to play a crucial role during inflammatory response. They produce toxic substances upon activation to destroy and remove bacteria, cells infected with bacteria and apoptotic/necrotic cells (Paul, 2003). These toxic substances which include proteolytic enzymes, nitric oxide and reactive oxygen species (Roitt and Delves, 2001) act on nearby cells and pathogenic agents by damaging cell membranes, proteins, lipids and genetic material. Our results therefore suggest that inflammation and the phagocytic cells associated with inflammation are a major source of the oxidative stress observed in the MSW management workers in this study. Similar correlation was made by Yeo et al. (2005) in patients with cancer, and this lends support to our present observation.

Furthermore, it is generally known that the human haematopoietic system is extremely sensitive to inflammation because of the rapid synthesis and destruction of cells with heavy metabolic demands. The significant decrease in the haemoglobin concentration of MSW management workers in this study supports the previous observation that adverse haematological effects of inflammation are mainly the result of its disturbance in the haem biosynthesis pathway (Subrahmanyam and Smith, 1997). This effect was also associated with significant decreases in PCV and MCV in the MSW management workers, further corroborating the deleterious influence of inflammation on the haematopoietic system. In spite of the observed inflammation and oxidative stress, our results reveal that renal function in the MSW management workers was still comparable with those of the control subjects as indicated by the similar BUN and creatinine levels. It is, however, difficult to suggest here that the renal function was not impaired in the MSW management workers because blood analysis of urea and creatinine are usually more sensitive when renal failure is advanced.

Similarly, the more specific marker enzymes for liver function, ALT and ALP, were not significantly different between MSW management workers and the control subjects. The significant elevation in AST in the MSW management workers may reflect either hepatic or extrahepatic tissue damage since this enzyme is also abundantly distributed in most cells or tissues of the body, making it not specific for liver function. In addition, the similar levels in plasma concentration of TC and TG in both control subjects and MSW management workers seem to suggest that the metabolic function of the liver was preserved. However, the significant decrease in plasma albumin may suggest a decrease in the synthetic function of the liver in these workers. It thus appears that exposure to MSW may predispose to impairment of liver function on prolonged exposure. We further observed that Cp and total leucocytes count exhibited significant positive correlation with job duration. Significant correlation between Cp and MDA level and between Cp and WBC was also observed in MSW management workers but such correlation was not seen in the control subjects.

In conclusion, the plasma levels of biomarkers of inflammation and oxidative stress assessed in this study were significantly elevated in MSW management workers. This revealed that systemic inflammatory processes that progressed to low-grade chronic inflammation and oxidative stress mechanisms are important biochemical and pathophysiological changes that contribute to the commonly observed general adverse health effects associated with occupational exposure to MSW. Our study also revealed that both Cp and WBC are rational systemic biomonitors, but the former (Cp) shows better reliance for assessing the overall health status of Nigerian WMWs.

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