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Original Article

Occupational Hazards and Safety Measures Amongst the Paint Factory Workers in Lagos, Nigeria

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ABSTRACT

Background: The manufacture of paint involves a variety of processes that present with medical hazards. Safety initiatives are hence introduced to limit hazard exposures and promote workplace safety. This aim of this study is to assess the use of available control measures/initiatives in selected paint factories in Lagos West Senatorial District, Nigeria.
Methods: A total of 400 randomly selected paint factory workers were involved in the study. A well-structured World Health Organization standard questionnaire was designed and distributed to the workers to elicit information on awareness to occupational hazards, use of personal protective devices, and commonly experienced adverse symptoms. Urine samples were obtained from 50 workers randomly selected from these 400 participants, and the concentrations of the heavy metals (lead, cadmium, arsenic, and chromium) were determined using atomic absorption spectroscopy.
Results: The results show that 72.5% of the respondents are aware of the hazards associated with their jobs; 30% have had formal training on hazards and safety measures; 40% do not use personal protective devices, and 90% of the respondents reported symptoms relating to hazard exposure. There was a statistically significant ($p < 0.05$) increase in the mean heavy metal concentrations in the urine samples obtained from paint factory workers as compared with nonfactory workers.
Conclusion: The need to develop effective frameworks that will initiate the integration and ensure implementation of safety regulations in paint factories is evident. Where these exist, there is a need to promote adherence to these practice guidelines.

1. Introduction

Work has its positive health-promoting effects, as the financial dividend provides the worker with the basic necessities of life [1]. The aforementioned translates into healthy well-being, job satisfaction, and ultimately, higher productivity. There is, however, a reciprocal and interactive relationship between the workers and the work environment [2]. The knowledge of these interactions between work and health is fundamental in understanding and practicing occupational health and safety [3], but the importance of safety at the workplace is often overlooked [4].

Occupational hazard is the risk, harm, or danger that an individual is exposed to at the workplace, whereas occupational diseases result from such exposures to the individual [5,6]. Although these occupational diseases appear to occur less frequently than other major debilitating diseases, there is evidence that they affect a considerable number of people, particularly in rapidly industrializing countries (e.g., Nigeria), hence indirectly impacting on the economy [7]. During work periods, workers are faced with a variety of hazards almost as numerous as the different types of work, including chemicals, biological agents, physical factors, and adverse ergonomic conditions. These are responsible for a variety of health consequences [4].

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Chemical substances, and their derivatives, are widely used in many sectors including industry, agriculture, mining, water purification, public health—particularly disease eradication—and infrastructure development. Their utilization has brought immense benefits to mankind. However, the production, storage, transportation, and removal of these substances can pose risks to people and the environment, and at the same time it has had negative impacts on human health and safety [8].

Solvents used in the paint industry for example have been shown in numerous studies to be the cause for negative health symptoms that include the central and peripheral nervous system as well as other organ systems. Various studies, as shown in Table 1, reveal the neurobehavioral effects of organic solvents in paints on paint factory workers/painters. The studies show exposure related negative effects, most commonly on tests of psychomotor function and short-term memory.

Also, some chemicals (organic and inorganic) used in paint industries contain heavy metals with known risks. Usually, the manufacture of paints involves a wide variety of raw materials that contain heavy metals such as lead, cadmium, and chromium pigments, and fungicides such as mercuric oxide [15] in the production process, which can present with medical hazards, some of which are easily recognized and others that may remain undetected for many years [16–18]. Lead and mercury, for example, have a serious and irreversible impact on the mental development of children [8]. Exposure to heavy metals has been shown to be associated with middle-term and long-term health risks such as abdominal pain and illness to the human fetus (causing abortion and/or preterm labor). Adults may also experience high blood pressure, fatigue, kidney, and brain disturbances [19]. Chronic exposure to heavy metals may also lead to skin eruptions, intestinal ulcer, and different types of cancers [20].

To control these medical hazards, particularly in relation to heavy metals, there are coordinated safety initiatives introduced to limit heavy metal exposures in the paint industry thereby preventing negative health effects. These measures include redesigning processes to place a barrier between workers and the hazard; adopting standard operating procedures or safe work practices; providing appropriate training, instruction, or information to reduce the potential for harm and/or adverse health effects to person(s); and implementing the use of personal protective devices (PPDs) such as gloves, glasses, aprons, safety footwear, and dust masks designed to reduce exposure to the hazard. PPDs are usually the last line of defense and usually used in conjunction with one or more of the other control measures [21].

The consequences of not following these practice guidelines can be fatal as control of these hazards is the key to reducing the risk of injury and illness among workers in this industry [18].

Our intention was to assess the awareness of workers on the occupational hazards present at work and the safety measures necessary in paint production factories. The study was also intended to highlight the common negative health symptoms experienced by paint factory workers. Another objective was to quantify the heavy metal concentrations in the urine of some selected paint factory workers.

2. Materials and methods

The study was designed to assess the occupational safety and concentration of heavy metals in the urine samples obtained from paint factory workers in Lagos West Senatorial District, Nigeria. The paint factory workers studied were factory production workers who were involved in the process of mixing raw materials and paint production, packaging of manufactured paints, and loading of paints into vehicles for appropriate distribution and marketing. A properly structured questionnaire adapted from the World Health Organization was used as a tool for data collection [5]. This study was undertaken for a period of 2 months.

2.1. Sample size determination and participant selection

A total of 400 consenting respondents were included in this study. This sample size has been found to be adequate for such a cross-sectional study [22]. The inclusion criteria called for factory workers in paint production factories in Lagos West Senatorial District. The estimated number of paint manufacturing establishments in Nigeria is 510, of which 228 are located within the three senatorial districts of Lagos. A total of 40 paint manufacturing factories were randomly (systematically with $n = 5$ factories) selected and used for this study. Ten factory workers were then randomly selected from each paint manufacturing establishment, making a total of 400 respondents.

2.2. Data collection

A self-administered well-structured standard questionnaire was designed and distributed to factory workers with the assistance of the factory supervisor for the purpose of gathering information from the respondents. The questionnaire elicited information on personal data, awareness of occupational hazards, and use of PPDs. The management personnel of the various paint manufacturers were adequately informed and were aware of the purpose of the study. They were also made to understand that participation in the study was voluntary and strict confidentiality was to be maintained.

2.3. Biological specimen collection and analysis of heavy metals

Fifty consenting factory workers were randomly selected from the 400 factory workers for urine heavy metals determination assay. The selected participants (paint factory workers) were age matched with the control participants (nonpaint factory workers) who were selected randomly from consenting students in the Department of Chemistry, University of Lagos, Lagos, Nigeria.

Table 1
Neurobehavioral effects of organic solvents in paints on paint factory workers/painters

Study	Exposed group (N)	Visual performance/motor deficit	Memory deficit	Behavioral symptoms
Bleeker et al (1991)[9]	Paint factory workers (187)	+	+	–
Maizlish et al (1987)[10]	Spray painters (124)	–	+	–
Fiddler et al (1987)[11]	Painters (101)			+
Cherry (1985)[12]	Painters (44)	+	+	+
Baker et al (1988)[13]	Painters (186)	+	+	+
Spurgeon et al (1992)[14]	Painters (90)	+	+	

+, Exposure-related effects observed; –, exposure related effects not seen.

Approximately 10 mL of urine was collected from all respondents with the aid of urine bottles. After each session, specimens were sent to the Central Research Laboratory of Chemistry Department, Faculty of Science, University of Lagos, Nigeria, for analysis. The urine samples were analyzed for heavy metals (lead, cadmium, arsenic, and chromium) concentrations using atomic absorption spectroscopy (Buck Scientific Inc. Connecticut, USA).

Briefly, whole samples (about 10 mL) were measured into a quartz beaker, then 10 mL of HNO_3 was added, and the mixture was gently heated on a hot plate until the brown fumes given off by the reaction turned white. The beaker was brought down from the hot plate to cool to room temperature. The concentrated mixture (containing the sample) was rinsed with 10 mL of deionized water and filtered (using Whatman filter paper) into a 25-mL standard volumetric flask. The Beer's law principle ($A = abc$) was used to plot the absorbance data against concentration, where A is the absorbance, a is the absorption coefficient (a constant that is characteristic of the absorbing species at a specific wavelength), b is the length of the light path intercepted by the absorption species in the absorption cell, and c is the concentration of the absorbing species. The specific wavelengths used were as follows: chromium, 357.87 nm; cadmium, 228.80 nm; Arsenic, 193.7 nm; and lead, 283.31 nm; the detection limits for the metals were as follows: lead, 0.05 mg/L; chromium, 0.02 mg/L; cadmium, 0.002 mg/L; arsenic 0.2 μg/L [23]. The calibration yielded a straight line, and the absorbance of solutions of unknown concentrations was measured and the concentration was determined from the calibration curve.

2.4. Data analysis

The data obtained from the questionnaires used in this study were analyzed using the EPI-INFO 2002 software program (EPI INFO was developed by the Center for Disease Control and Prevention, USA). The data were presented in frequency distribution tables with percentages; heavy metals analysis results were expressed as mean ± standard deviation. The Student t test analysis was used to determine the differences between samples. Results were considered to be significant at $p \leq 0.05$.

3. Results

Table 2 shows the demographical characteristics of the study population. It was observed that the majority of the respondents were within the age range of 25–34 years (45.75%). Also, sex distribution shows a predominantly male setting with 62% being males and females 38%. This gives an approximate male/female ratio of 2:1. The collected data revealed that the majority of the paint factory workers had secondary education (44.5%), and 78% had more than primary education. Most of the respondents (~40%) had been working in the paint industry for 3–5 years. Table 3 shows the perceptions of the workers to the hazards associated with their job and an assessment of their adherence to prescribed safety measures. The results show that among our respondents, the level of occupational hazard awareness is high (72.5%). However, the majority (60.75%) of these workers had not been formally trained on occupational hazard and safety. Some of the respondents (58.5%) use PPDs; however, only 25.5% of them use these devices frequently. Table 4 shows the PPDs and their frequency of use among the respondents. The results reveal that the larger percentages of the respondents do not use these devices. In detail, 85.8% do not use hand gloves, 61.5% do not use goggles, 74.75% do not use safety boots, 66.75% do not use dust masks, and 61.5% do not use aprons. Table 5 shows the commonly reported negative health symptoms among the respondents. Overall, 90% of the respondents had symptoms relating to hazard exposure, whereas only 10% reported that they were symptoms-free. Headache was the most frequently reported health effect (33.75%). Others include chronic fatigue (10.5%), skin irritation (8.75%), eye irritation (6.25%), and itching (5.5%). Table 6 shows the mean heavy metal concentrations (μg/mL) in the urine samples of paint workers and non-paint workers. The results show statistically significant ($p < 0.05$) increases in urine concentrations of lead, cadmium, arsenic, and chromium among paint workers compared to nonpaint workers.

Table 2
Demographic characteristics of respondents

Variable	Frequency	%
Age (y)		
17–24	107	26.75
25–34	183	45.75
35–44	61	15.25
>44	49	12.25
Total	400	100
Sex		
Male	248	62
Female	152	38
Total	400	100
Educational level		
No formal education	36	9
Primary	52	13
Secondary	178	44.5
Technical	79	19.75
Tertiary	55	13.75
Total	400	100
Duration of employment (y)		
0–2	82	20.50
3–5	159	39.75
6–8	101	25.25
> 8	58	14.50
Total	400	100

4. Discussion

Over the past half-century, there has been an accelerated release of artificial chemicals into the environment, many of whose impacts are not well known. We do know, however, that industrial development in many countries has carried along with it significant health implications, which are narrowly defined by those concerned with occupational or individual health safety, as the health consequences of workers exposed to specific hazardous processes, materials, or environmental conditions are associated with the workplace [6].

Table 3
Awareness of occupation hazards and safety measure utilization

Variable	Frequency	%
Are you aware of the hazards associated with this job?		
Yes	290	72.5
No	68	17
No response	42	10.5
Total	400	100
Have you had formal training hazards and safety measures to be taken?		
Yes	132	33
No	243	60.75
No response	25	6.25
Total	400	100
Do you use of personal protective devices?		
Yes	234	58.5
No	120	30
No response	46	11.5
Total	400	100
How often do you use personal protective devices?		
Regularly	102	25.5
Occasionally	132	33
Never	120	30
No response	46	11.5
Total	400	100

Table 4
Use of personal protective devices among respondents

Personal Protective Device	Frequency	%
Hand gloves		
Use	58	14.5
Don't use	342	85.5
No response	0	0
Total	400	100
Goggles		
Use	112	28
Don't use	246	61.5
No response	42	10.5
Total	400	100
Safety boots		
Use	101	25.5
Don't use	299	74.75
No response	0	0
Total	400	100
Dust masks		
Use	100	25
Don't use	267	66.75
No response	33	8.25
Total	400	100
Aprons		
Use	112	28
Don't use	246	61.5
No response	42	10.5
Total	400	100

The aim of this study is to provide data that will indicate the risks posed to factory workers in the paint industry, particularly from exposure to raw materials and solvents containing heavy metals and thus provide an impetus that will drive implementation of occupational safety standards. This is especially important because, although progress has been made in developing a regional framework for the management of chemicals throughout their life cycle—production, transportation, storage, use, and disposal—much still needs to be done in integrating them for implementation [8].

Results from this study show that a majority (about 50%) of the respondents have at least secondary education, and 72.5% (290/400) are aware of the hazards associated with their jobs; however, only one-third have had formal training on hazards and safety measures necessary on the job. Consequently, more than 40% do not use PPDs, and of those who do, only 25% use these devices regularly. A previous study in Tanzania also reported a low use of PPDs [24].

Table 5
Self-reported occupational health problems among respondents

Symptoms	Frequency	%
Multiple symptoms	360	90
Headache	135	33.75
Memory loss	3	0.75
Dizziness	15	3.75
Anxiety	20	5
Sleep disorder	7	1.75
Poor eye sight	5	1.25
Skin irritation	35	8.75
Frequent disorder	3	0.75
Itching	22	5.5
Weight loss	15	3.75
Nose bleeding	8	2
Chronic fatigue	42	10.5
Eye irritation	25	6.25
Chest pain	3	0.75
Cough—dry	7	1.75
Cough—productive	15	3.75
No symptoms	40	10
Total	400	100

Table 6
Urine heavy metal concentration

Heavy metals	Paint workers	Nonpaint workers
Lead (μg/L)	$240 \pm 20^*$	110 ± 10
Cadmium (μg/L)	$50 \pm 7^*$	6 ± 2
Arsenic (μg/L)	$40 \pm 5^*$	2 ± 0.4
Chromium (μg/L)	$200 \pm 20^*$	0.8 ± 0.3

Result shows the mean ± standard deviation of the urine concentration of heavy metals (μg/L). Number of participants for each group, 50.
*Statistically significant at $p < 0.05$.

The gross inadequacy of adherence to occupational safety measures is further highlighted when specific PPD use is evaluated: 85.5% do not use hand gloves, 61.5% do not use goggles, 74.5% do not wear safety boots, 66.75% do not use dust masks, and 61.5% do not wear aprons. In controlling medical hazards in the paint industry especially for heavy metals, safety measures are directed at limiting heavy metal exposures. The use of PPDs is strongly recommended and is usually in conjunction with one or more of the other control measures [21]. The consequences of not following these practice guidelines can be fatal as control of these hazards is the key to reducing the risk of injury and illness among workers in this industry [18].

It was also observed that only 10% (40/400) of the respondents reported that they were symptoms-free, whereas the other 90% of the respondents had symptoms relating to hazard exposure with headaches being the most frequent (33.75%). Others include chronic fatigue (10.5%), skin irritation (8.75%), eye irritation (6.25%), and itching (5.5%). Although this study did not directly link the cause of these effects to the chemicals (solvents and heavy metals containing raw materials) used in this industry, previous investigations have shown that they are linked. Previous studies into negative health symptoms observed in paint factory workers/painters have reported neuropsychological symptoms including impairments of memory, perceptual speed, manual dexterity [25], psychomotor coordination [26], and nonverbal skills [27]. A decrease in olfactory functions [28], such as reduced two-point discrimination ability in the lower extremities [10] and color vision loss [29], has also been reported.

Furthermore, there were statistically significant ($p < 0.05$) increases in the mean urine heavy metal concentrations in samples obtained from paint workers as compared with the nonpaint workers.

The mean lead (Pb) urine concentration of 240 μg/L detected in urine samples from paint factory workers was significantly higher and twice that found in nonfactory workers (110 μg/L). Human exposure to lead is common and results from the numerous uses of this metal because of its exceptional properties. The industrial use of lead is common in the manufacture of corrosion- and acid-resistant materials used in the building industry. In occupational settings, the major routes of lead exposure are inhalation and ingestion of lead-bearing dusts and fumes. Independent of the route of exposure, absorbed lead is primarily excreted in urine and feces; sweat, saliva, hair and nails, and breast milk are minor routes of excretion [30]. Measurements of urinary lead levels have been used to assess lead exposure [31–33]. In a recent study of Egyptian policemen, urinary excretion was positively correlated with duration of exposure to lead from automobile exhaust [33]. However, urinary lead excretion reflects, mainly, recent exposure and, thus, shares many of the same limitations for assessing lead body burden or long-term exposure [34]. Drawing inference from this, the results show that workers in paint factories are acutely (at least) twice at risk for exposure to lead than the general population. Symptoms of acute lead poisoning are headache, irritability, abdominal pain, and various symptoms related to the nervous system—symptoms that are also reported by the respondents in this study.

Except for those who live near cadmium-emitting industries, inhalation of cadmium in the ambient air may occur but is not a major source of exposure. Smokers and people living in contaminated areas have higher urinary cadmium concentrations, with smokers having about twice as high concentrations as nonsmokers [35]. Blood cadmium tends to reflect recent exposures and urinary cadmium reflects cumulative cadmium exposure and body burden (particularly, kidney cadmium levels). Sensitive areas are the kidney and bone following oral exposure, and the kidney and lung following inhalation exposure. Effects that have been observed in humans and/or animals include reproductive toxicity, hepatic effects, hematological effects, and immunological effects. Although acute pulmonary effects and deaths are uncommon, sporadic cases still occur [36]. Because the toxicity of cadmium is dependent on its concentration in the kidney, adverse effects in humans are typically not observed after shorter durations. Drawing inferences from the present results, the mean cadmium (Cd) urine concentration of 50 μg/L detected in urine samples from paint factory workers was eight times (and significantly) higher than that found in nonfactory workers (6 μg/L). Cadmium excretion in urine of occupationally exposed workers increases proportionally with body burden of cadmium, but the amount of cadmium excreted represents only a small fraction of the total body burden unless renal damage is present; in this case, urinary cadmium excretion markedly increases [37]. It has been suggested that the tubular damage is reversible [38], but there is overwhelming evidence that the cadmium-induced tubular damage is indeed irreversible [35]. Baring cases of renal damage, our results suggest that workers in paint factories have on average six times the cadmium body burden of the general population.

The principal route of exposure to arsenic for the general population is likely to be the oral route, and exposure to arsenic from other pathways is generally small, but may be significant for areas with high levels of arsenic contamination particularly in occupational settings. Increased risk of lung cancer, respiratory irritation, nausea, skin effects, and neurological effects have been reported following inhalation exposure [39]. Human data suggest that dermal or respiratory effects may be the most prevalent [40,41]; respiratory or immunological effects appeared to be the most common following inhalation exposure to inorganic arsenic in animals [42]. In occupational settings, only small amounts of arsenic will be absorbed through the dermal route, so this is usually not a source of concern. However, typical dermal effects that may follow both oral and dermal exposure include hyperkeratinization of the skin (especially on the palms and soles), formation of multiple hyperkeratinized corns or warts, and hyperpigmentation of the skin with interspersed spots of hypopigmentation. Arsenic is a known human carcinogen by both inhalation and oral exposure routes [39]. By the inhalation route, the primary tumor types are respiratory system cancers, although a few reports have noted increased incidence of tumors at other sites, including the liver, skin, and digestive tract [39]. The mean arsenic urine concentration of 40 μg/L detected in urine samples from paint factory workers was 20 times higher than that found in nonfactory workers (2 μg/L). The urinary excretion of arsenic appears to account for 30–60% of the inhaled dose [42]; this suggests that nearly all arsenic that is deposited in the lung is excreted in the urine. We can thus infer that paint factory workers may be exposed to as high as 20 times more arsenic than the general population. The time course of excretion in humans exposed by inhalation has not been thoroughly investigated, but urinary arsenic levels in workers in a smelter rose within hours after they came to work on Monday and then fell over the weekend [43]. This implies that excretion is fairly rapid, and this is supported by intratracheal studies in rats [44] and hamsters [45], where whole-body clearance of administered arsenate or arsenite occurred with a half-time of 1 day or less. However, the study in rats [44] found that the clearance was biphasic, with 95% cleared with a half-time of 29 minutes and the remaining arsenic cleared with a halftime of 75 days.

Chromates are used in the manufacture of cements, leather products, anticorrosives, and paints. The mean chromium (Cr) urine concentration of 200 μg/L detected in urine samples from paint factory workers was a massive 250 times higher than that found in nonfactory workers (6 μg/L). The primary route of exposure in nonoccupational workers is through contaminated food ingestion. Present-day workers in chromium-related industries can be exposed to chromium concentrations 2 orders of magnitude higher than the general population [46]. The primary effects associated with exposure to chromium compounds are respiratory, gastrointestinal, immunological, hematological, reproductive, and developmental. In addition, dermal and ocular irritation may occur from direct contact. Occupational exposure to chromium compounds in various industries has also been associated with increased risk of respiratory system cancers, primarily bronchogenic and nasal [46]. Normal urinary levels of chromium in humans have been reported to range from 0.22 μg/L to 1.8 μg/L [47,48], which is very much lower than the values obtained from this study. However, this study did not investigate the urinary concentrations of these harmful elements in relation to the use and nonuse of PPDs; thus, this should be investigated in future studies. It is also important to assay the urinary metal concentration by sex stratification as sex is one of the fundamental components for biologic samples.

In conclusion, the results highlight a lack of adequate work safety practices in the paint factories of Lagos West Senatorial District. An overall assessment shows gross deficiencies in training on workplace hazards/safety measures and also in the use of appropriate PPDs. Consequently, the majority of the workers report adverse health symptoms evidenced by significant increases in the urinary heavy metals concentrations of these workers when compared with the general population.

Given that adherence to safety practice guidelines is the key to reducing the risk of injury and illness among workers in this industry, there is the need to develop a framework that will initiate the integration and implementation of safety regulations and guidelines in the paint factories so as to reduce associated occupational hazards.

Conflicts of interest

All authors declare no conflicts of interest.

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