



Comparative Assessment of Formaldehyde Concentrations in Public and Private Mortuaries in Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2019/v23i230115

Editor(s):

(1) Dr. Mahmoud Nasr, Sanitary Engineering Department, Faculty of Engineering, Alexandria University, Egypt.

Reviewers:

(1) Meer Ahmad A. Mydin Meera, Malaysia.

(2) Switbert Rwechungura Kamazima, Muhimbili University of Health and Allied Sciences, Tanzania.

Complete Peer review History: <http://www.sdiarticle3.com/review-history/48312>

Received 22 January 2019

Accepted 30 March 2019

Published 13 April 2019

Short Research Article

ABSTRACT

Introduction: Formaldehyde is an industrial chemical that is classified as a volatile organic compound (VOC). It is commonly use in mortuaries for the preservation (embalmmnt) of the dead in Rivers State. Mortuary workers are occupationally exposed to formaldehyde by inhalation and skin contact. This objective/aim of the study was to measure and compare the concentration of formaldehyde in public and private mortuaries of Rivers State, Nigeria.

Methodology: This cross-sectional (field) survey was carried out in 9 public and 6 private mortuaries in Rivers State. The Time-Weighted Average (TWA) and short- Term Exposure Limit (STEL) of formaldehyde concentrations in the embalmmnt sections of the mortuaries were measured using a suitable formaldehyde gas detector instrument. The mortuaries were selected by a multistage sampling technique. Data were collected, entered and analyzed using XL STATA and SPSS and presented in tables and graphs.

Results: The mean TWA concentration of formaldehyde in public and private mortuaries was 2.42+-1.77 and 2.52+-0.99 ppm respectively. Also, the STEL concentration measured in public and private mortuaries were 0.91+-0.99 and 1.93+-1.22 ppm. The 8 hour TWA values exceeded OSHA (0.75) and NIOSH (0.016 ppm) standards.

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Conclusion: There was a high concentration of formaldehyde in both public and private mortuaries which may pose high risk to the health of the mortuary workers of Rivers State. The study recommended health education and surveillance among mortuary workers and good engineering design in the mortuary.

Keywords: Formaldehyde; public mortuaries; private mortuaries; mortuary workers; exceedance factors; coefficient of variation; health effects.

1. INTRODUCTION

Formaldehyde (FA) is one of the industrial chemicals that is produced all over the world and widely used in many factories/ industries due to its adhesive, preservative and antiseptic properties [1]. FA, though a natural product in most living systems is formed endogenously in mammals including humans, as a consequence of oxidative metabolism. In addition to its wider use in industries, science laboratories and household, the potential for its occupational and environmental exposure is increasing [1,2]. Currently, China remains the highest producers and consumers of formaldehyde worldwide [1].

International Agency for Research on Cancer [3] classified Formaldehyde as a carcinogen based on its association with nasopharyngeal cancer. Several cohort studies in the United States among industrial workers exposed to FA have showed significant excess of deaths from nasopharyngeal cancer in comparison to the US national population [4]. Hauptmann et al., [5] in their study "Mortality from Lympho hematopoietic malignancies among workers in FA industry" found that an excess of deaths from nasopharyngeal cancer occurred in a proportional mortality analysis of the largest US cohort of embalmers. The result of this study further corroborated the finding by [6] in a study conducted among male employees in Denmark. Though, the general population is exposed to FA, because of its presence in the environment, it is usually at low levels (less than 0.03 parts per million (ppm) parts of air). However, industrial workers who produce FA or FA containing products [1], human anatomists, laboratory technicians and morticians in most developing countries (including Nigeria), where over 95% of human (body parts) embalment/preservation is done with aqueous solution of formaldehyde (Formalin), are occupationally exposed to higher levels of FA than the general Nigeria populations.

Exposure occurs primarily by inhaling the FA gas or vapours from the enclosed air or by absorbing liquids containing FA through the skin [1]. Ki-

Hyun's study [1] has shown that mortuary workers are exposed to high concentrations of formaldehyde.

Empirical evidence from studies in China and United States have shown an association between FA occupation exposure and multiple adverse health effects such as asthma, nasopharyngeal cancers and myeloid leukemia [1,7]. Other studies indicated that evaluated environmental exposure to FA impeded sperm morphology in men and increased the rate of miscarriages, endometrioses and prolonged pregnancies in women and further increase the risk of having a child with mental retardation, learning disabilities or behavior problems [8].

FA is a widely used chemical in Nigerian mortuaries, as a preservative (Tissue Fixative), adhesive and anti-septic. In fact, FA- based aqueous solution (Formalin) is the main stay of corpse preservation (Embalment) in Nigeria and most developing African countries. Morticians remain the highest category of workers that use FA for preservation of the dead. This category of workers in Nigeria are poorly recruited. In most cases, the mortuary proprietors neither offer pre- employment medical examination, training nor carry out periodic medical examinations on them. Studies have revealed that most mortuaries do not have standard operating procedure (SOP) or occupation regulatory framework/body that enforces any existing laws [1]. Permissible exposure level (PEL) of FA and other chemicals in Nigeria are not well documented and defined. The Federal Ministry of Labour and Productivity, saddled with that responsibility has not taken the issue of occupational health seriously despite the strong agitation by Nigeria Labour Congress (NLC).

In Nigeria, there is paucity of scientific information relating to the occupational exposure/effects of FA on morticians and this necessitated the conduct of this study. Oloto [9] carried out a study on the "assessment of the effect of formaldehyde exposure on the liver in

mortuary workers in south western Nigeria". The study analyzes the blood samples of some mortuary workers and found that FA impairs the synthetic function of the liver. However, he did not measure the concentrations of FA in the mortuaries to which these workers are exposed that resulted in liver impairment. Therefore this study was designed to measure and compare the concentrations of FA in public and private mortuaries in Rivers State.

2. METHODOLOGY

The study area is Rivers State situated in the Niger-Delta (South-South) region of Nigeria. It is located between latitudes 4.74974° and longitude 6.82766°. The State has 23 Local Government Areas (LGAs) out of which 15 LGAs with functional mortuaries were selected for the study. Mortuaries that make use of formalin (37% solution of FA) for the embalment or preservation of corpses in the 15 Local Government Areas of Rivers State were chosen. The study was conducted based on the consent of the mortuary owners and operators and acceptable of research protocol. The mortuaries were stratified into private and public mortuaries. Hence, a total of fifteen mortuaries (7 public and 8 private) in the Fifteen LGAs were finally selected and sampled.

FA gas detector was used to measure the concentration of FA gas in the embalment section of the mortuaries. In order to meet international standards, and for results from this study to be accepted for publication, a specific and sensitive FA gas detector was ordered from China to measure the FA gas in the embalment section of the mortuaries studied (Fig. 1). A GLOBE Instrument, model PGas-20 CH₂O gas detector (Fig. 1) was used to measure the concentrations of FA in the mortuaries. The instrument was manufactured in November 2017 by Globe instrument and marketed by Henan Zhiyi System Engineering Co., Ltd. China. The instrument has a built-in pump and a 20 cm long probe as shown in Fig. 1. It was calibrated in the factory and also has built-in calibration coefficients with auto zeroing mechanism. The measurement range of the instrument is 0 – 10ppm, resolution/detection limit is 0.01 ppm and the response time is ≤20s. The measurement principle is photo ionization detection (PID).

The study used both the time weighted average concentration of FA in the workplace of the mortuaries. The instrument displayed the time

weighted average (TWA) and short time exposure limit (STEL) concentrations of FA as well as the maximum values of each. The instrument was place 1.2 meters above ground level in each of the mortuaries. The TWA readings were taken every 1 hour interval for 8 hours, while the STEL readings were taken after every 15 minutes in compliance with Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH) standards.



Fig. 1. PGas-20 CH₂O gas detector

2.1 Data Analysis

The data obtained from the 7 public mortuaries and 8 private mortuaries were averaged, aggregated and categorized as public mortuary and private mortuary data respectively. Statistical analyses were accomplished using XLSTAT-2018 Premium version software developed by Addin soft [10] and Statistical Package for the Social Science (SPSS) software version 22, originally developed by International Business Machines (IBM). Descriptive statistics were used to determine the measures of central tendency (mean, median, and mode) and coefficients of variation of the concentrations of FA measured in the mortuaries. The exceedance factor (a factor by which the mean value exceeds the limit) was computed using Equation (1). The coefficient of variation of the measured data was computed as the percentage ratio of the standard deviation to the mean value.

The Exceedance Factor (EF) was calculated as follow:

$$\text{Excedence Factor (EF)} = \frac{\text{Observed mean concentration of formaldehyde}}{\text{Mean standard}} \quad (1)$$

The computed exceedance factors were expressed in terms of low, moderate, high

and critical [11]. Where: <0.5 is low; 0.5-1.0 is moderate; 1.0-1.5 is high; >1.5 is very high.

The concentration ranges for different levels have been selected based on the OSHA Occupational Exposure Standards for FA by calculating the exceedance factor. Measured concentrations of FA were compared with Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH) standards. Coefficient of variation of measured FA concentrations was calculated using Equation (2).

$$\%CV = \frac{S}{\bar{X}} = \frac{\sqrt{\frac{\sum (X_i - \bar{X})^2}{N-1}}}{\frac{\sum X_i}{N}}$$

Where X_i is the i^{th} data sample, \bar{X} is the mean, s is the standard deviation and N is the total number of data samples.

The minimum and maximum concentrations for both the public and private mortuaries are presented; the mean, standard deviation, and coefficient of variation were statistically computed as presented; the coefficient of variations (CV) in the FA concentrations in the public and private mortuaries were computed as the ratio between the standard deviation to the mean and determines the relative percentage of deviation from the mean values.

2.2 Ethical Consideration

An approval letter to proceed with the study was obtained from the Center for Occupational Health, Safety and Environment (COHSE) of the University of Port Harcourt. The letter was presented to the mortuary operators seeking for their permission to carry out the monitoring, thus the consent of the mortuary proprietors was duly obtained. All mortuary proprietors were assured of maximum confidentiality and that information derived will be used mainly for research purposes.

2.3 Study Limitation

Initially, mortuary proprietors were adamant in accepting the study, having a feeling that results will discourage workers from continuing to work

in the mortuaries in view of perceived health implications. However, their fears were allayed after they were told that the study was for academic purpose and the names of their mortuaries would not be disclosed and that they will also benefit from the findings of the study when it will be published.

3. RESULTS AND DISCUSSION

The aggregated averaged values of the TWA concentrations of FA in both the public and private mortuaries are shown in Table 1; while the aggregated averaged values of the STEL concentrations of FA in both the public and private mortuaries are shown in Table 2. Descriptive statistics of the TWA data set are presented in Table 3. Plots of daily TWA and STEL FA concentrations are shown in Figs. 2 and 3. The mean TWA values in comparison with OSHA and NIOSH standards are shown in Fig. 4; while the STEL mean values in comparison with OSHA and NIOSH standards are shown in Fig. 5. Computed coefficient of variations and exceedance factors for both TWA and STEL in the mortuaries are presented in Tables 4 and 5 respectively. The box plots of TWA and STEL values are shown in Figs. 6 and 7 respectively; while the scatter plots showing the variations of FA concentrations with time is shown in Fig. 8.

The minimum, maximum, mean, median and standard deviation of the concentrations of FA in public and private mortuaries are shown in the descriptive statistics of Table 3.

The TWA concentrations of FA measured in public mortuaries (Table 1 and Fig. 2) ranged from 0.0 ppm to 8.25 ppm with a mean and standard-deviation of 2.42 ± 1.77 ppm; while TWA concentrations measured in private mortuaries (Table 1 and Fig. 2) ranged from 1.18 ppm to 4.58 ppm with a mean and standard-deviation of 2.52 ± 0.99 ppm. The STEL concentrations measured in public mortuaries (Table 2 and Fig. 3) ranged from 0.0 ppm to 3.53 ppm with a mean and standard-deviation of 0.91 ± 0.99 ppm; while the STEL measured in private mortuaries (Table 2 and Fig. 3) ranged from 0.0 ppm to 4.32 ppm with a mean and standard-deviation of 1.93 ± 1.22 ppm. Winkler, [12] in his study "Formaldehyde Exposures in a University Anatomy Laboratory" obtained a mean 8-hour TWA 0.33 ppm and a mean STEL concentration of 6.6 ppm among mortuary student during embalment. Also Chia et al., [13] in their study

“Medical students’ exposure to formaldehyde in a gross anatomy laboratory dissection laboratory” obtained a mean formaldehyde concentration of 0.74 ppm in the breathing zone samples and 0.50 ppm for area samples. These values are lower than the mean 8-hour TWA obtained in this study (Figs. 4 and 5). Poor engineering and administrative control measures, poor mixing procedures, lack of standards operating procedure (SOP), poor ventilations, different embalming fluids used and different embalming tables were some of the factors observed during monitoring, which accounted for the high levels of formaldehyde in the air environment of the mortuaries.

Table 1. Time weighted average (TWA) concentrations of formaldehyde (ppm)

Time (hour)	Public mortuaries	Private mortuaries
1	8.25	4.58
2	4.75	3.55
3	3.33	3.35
4	2.75	2.92
5	2.12	2.85
6	1.53	2.76
7	1.03	2.35
8	0.45	1.45
9	4.52	3.09
10	3.15	2.0
11	2.45	1.66
12	2.12	1.62
13	1.0	1.35
14	0.91	1.27
15	0.12	1.18
16	0.0	1.18
17	3.44	4.21
18	3.46	1.6
19	2.96	3.01
20	2.65	3.65
21	2.24	2.93
22	1.83	2.67
23	1.75	1.98
24	1.38	3.21
Range	0.0-8.25	1.18-4.58
Mean	2.42	2.52
Stdv	1.77	0.99
OSHA limit	0.75	0.75
NIOSH limit	0.016	0.016

The mean TWA value of FA in the public mortuaries exceeded OSHA TWA limit by 222.7%; while the TWA mean value in the private

mortuaries exceeded the limit by 236%. A t-test statistical analysis showed that the difference between the TWA mean concentrations of FA in the public and private mortuaries is significant at 95% confidence interval ($p < 0.05$) as shown in Table 6. The mean STEL values of FA in both the public and private mortuaries are below the OSHA STEL limit, however, the mean STEL value in the private mortuaries was close to the limit by 4%. A t-test statistical analysis showed that the difference between the STEL mean concentrations of formaldehyde in the public and private mortuaries is highly significant at 95% confidence interval ($p < 0.05$) as shown in Table 7. This result implies that the FA concentration levels in private mortuaries are high compared to public mortuaries. The concentration levels of FA in both private and public mortuaries exceeded stipulated limits and may pose long time adversely affects to the health of the mortuary workers.

Table 2. Short-Term Exposure Limit (STEL) concentrations of Formaldehyde (ppm)

Time (minute)	Public Mortuaries	Private Mortuaries
15	0.51	4.32
30	0.47	3.44
45	0.33	3.3
60	0.23	2.68
75	0.11	1.45
90	0.09	1.83
105	0.0	3.46
120	0.0	2.24
135	0.54	4.32
150	0.52	3.14
165	0.42	2.47
180	0.42	1.12
195	0.4	1.11
210	0.39	1.05
225	0.36	0.86
240	0.34	0.68
255	3.53	1.78
270	2.76	2.1
285	2.62	0.9
300	2.14	1.2
315	2.03	1.6
330	1.65	0.8
345	1.05	0.4
360	0.98	0.0
Range	0.0-3.53	0.0-4.32
Mean	0.91	1.93
Stdv	0.99	1.22
OSHA limit	2.0	2.0
NIOSH limit	0.1	0.1

Table 3. Descriptive statistics of the data set

Statistic	Public Mortuaries	Private Mortuaries
Nbr. of observations	24	24
Minimum	0.000	1.180
Maximum	8.250	4.580
Median	2.180	2.715
Mean	2.425	2.518
Standard deviation	1.768	0.986

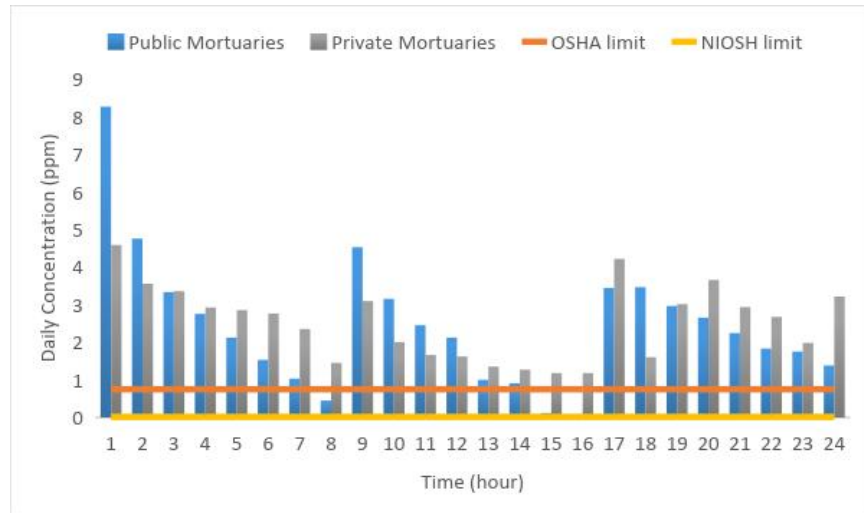


Fig. 2. Daily TWA concentrations of formaldehyde measured in public and private mortuaries

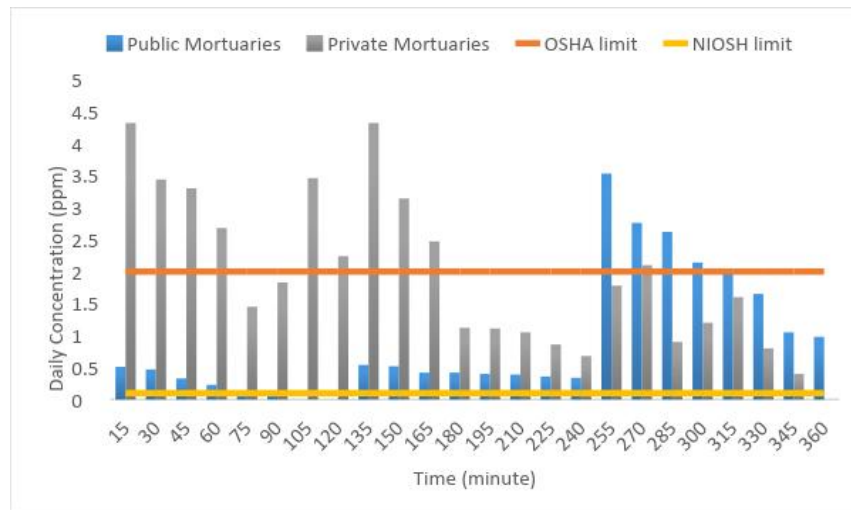


Fig. 3. Daily STEL concentrations of formaldehyde measured in public and private mortuaries

Table 4. Statistics of formaldehyde time weighted average in the mortuaries

Mortuary	Min (ppm)	Max (ppm)	Mean (ppm)	Stdv. (ppm)	OSHA Limit	CV (%)	EF	Rating
Public Mortuary	0.0	8.25	2.42	1.77	0.75	73.14	3.23	Very high
Private Mortuary	1.18	4.58	2.52	0.99	0.75	39.29	3.36	Very high

Stdv. = standard deviation; *CV* = coefficient of variation; *EF* = exceedance factor

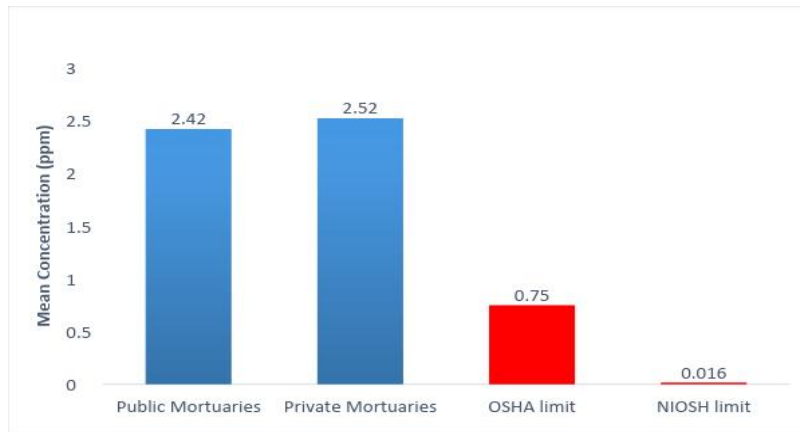


Fig. 4. TWA mean concentrations in both public and private mortuaries in comparison with OSHA and NIOSH standards

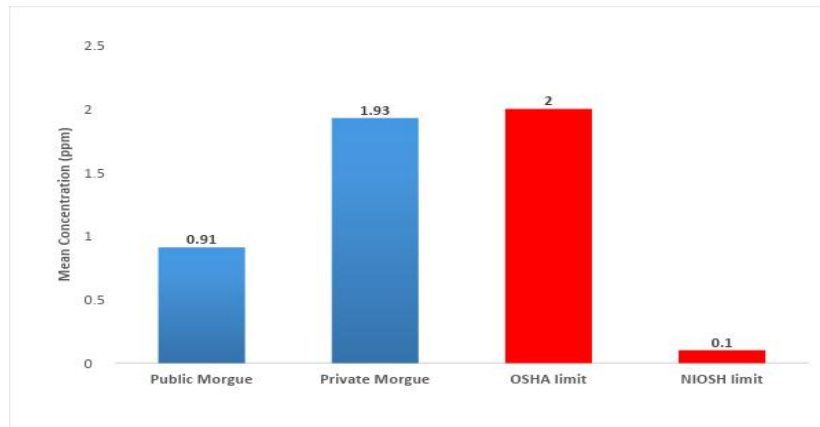


Fig. 5. STEL mean concentrations in both public and private mortuaries in comparison with OSHA and NIOSH standards

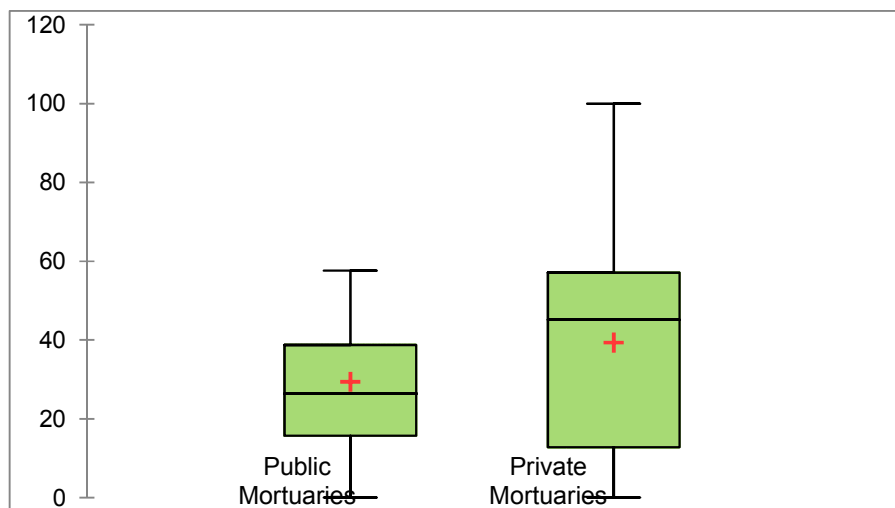


Fig. 6. Univariate box plots of time weighted average values

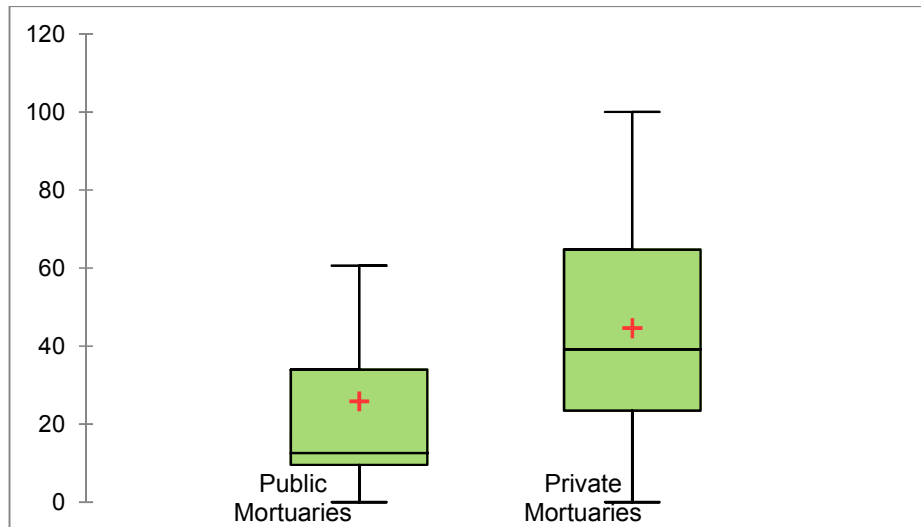


Fig. 7. Univariate box plots of short time exposure limit values

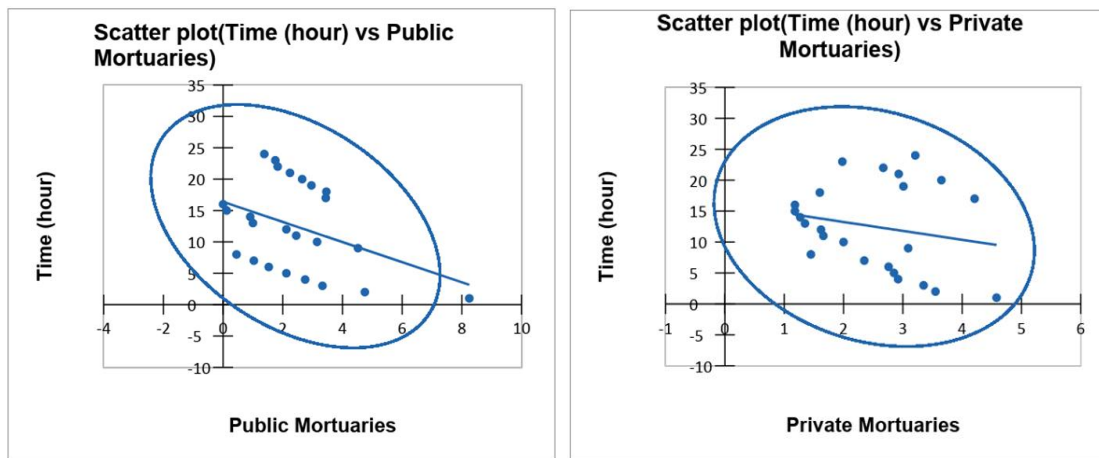


Fig. 8. Scatter plots of formaldehyde concentrations in the mortuaries

Table 5. Statistics of formaldehyde short-term exposure limit in the mortuaries

Mortuary	Min (ppm)	Max (ppm)	Mean (ppm)	Stdv. (ppm)	OSHA Limit	CV (%)	EF	Rating
Public Morgue	0.0	3.53	0.91	0.99	2.0	108.79	0.455	Very low
Private Morgue	0.0	4.32	1.93	1.22	2.0	63.21	0.965	Low

Stdv. = standard deviation; CV = coefficient of variation; EF = exceedance factor

Table 6. Result of t-test analysis of TWA

	t	df	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference	
					Lower	Upper
Public Mortuaries	6.718	23	.000	2.42458	1.6780	3.1712
Private Mortuaries	12.514	23	.000	2.51750	2.1014	2.9336

Table 7. Result of t-test analysis of STEL

	t	df	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference	
					Lower	Upper
Public Mortuaries	4.508	23	.000	.91208	.4935	1.3306
Public Mortuaries	7.710	23	.000	1.92708	1.4100	2.4441

A t-test analysis for both the public and private mortuaries indicate high percentage in public mortuaries compared to the private ones. This could implies that public mortuaries have relatively good dispersion compared to private Mortuaries. It was observed that poor ventilation and lack of safety rules or standards operating procedure (SOP) were responsible for the high levels of FA in the embalmmnt section of the mortuaries, especially in the private mortuaries. Formaldehyde concentration was observed to reach maximum during embalmmnt and then decreases gradually albeit slowly at the end of the embalmmnt. Formaldehyde concentrations in the air decrease faster with time in public mortuaries compared to private mortuaries as shown in Fig. 8 because the public mortuaries have relatively good ventilation compared to private mortuaries. Computed exceedance factors for both the public and private mortuaries based on long time TWA are 3.23 and 3.36 respectively rated as very high. This indicates that the level of FA in the mortuaries may pose long-term hazards to the health of the morticians. Similarly, computed exceedance factors based on STEL for both the public and private mortuaries show low acute health effects in the public mortuaries and moderate acute effects in private mortuaries. FA effect is dose-dependent (Andersen et al., [14] and continuous inhalation might have prolong health effects, thus, chronic health effects are envisaged among workers in both the public and private mortuaries in the State.

The high concentration levels of FA observed in both the public and private mortuaries may cause severe irritation of the eyes, and affect the mucous membrane of the upper respiratory system. FA concentrations between 0.1 ppm and 0.5 ppm have been found to cause nasal and eye irritation, neurological effects, increased risk of asthma and/or allergies [15], concentrations between 0.6 ppm and 1.9 ppm may cause nasal and eye irritation, eczema, change in pulmonary function. Other health effects reported include dry and sore throat, eye-irritation, increased thirst and sleep disturbance among mortuary workers [15]. Study by Lang et al., [16] on "Formaldehyde

and chemosensory irritation in humans: A controlled human exposure study" indicated that concentrations ranging from 0.4ppm to 3.0ppm cause irritation of the nose, throat and eyes. Concise International Chemical Assessment Document 40 (CICAD) by the World Health Organization [17] showed that individual exposed to formaldehyde concentration levels ranging from 0.25 ppm to 3.0 ppm result in respiratory tract problems, irritation of the eyes and headache [17]. Moderate sensory eye, nose, and throat irritation were also experienced by individuals exposed for a short time to levels of formaldehyde in this range. Tang et al. [2] in their study on "Formaldehyde in China" reported headache, sore throat, coughing, and shortness of breath, as well as blurred vision and vomiting as some of the health effects of formaldehyde among mortuary workers. Kryzanowski et al [18] in their study "Chronic respiratory effects of indoor FA exposure" have associated FA exposure with diseases such as pulmonary function, asthma, chronic bronchitis and other chronic respiratory symptoms.

Mortuary workers can be protected through engineering (fume-cupboards, local-exhaust ventilation, and good general ventilation) and administrative controls, best work practices and procedures, use of personnel protective equipment, regular air monitoring of morgues, training of workers and worker medical surveillance. Mortuary workers should be educated on the hazards associated with poor handling and inhaling high concentrations of FA.

Regulatory bodies like the National Institute for Occupational Safety and Health (NIOSH) and Occupational Safety and Health Administration (OSHA) in the United States have set standards and permissible exposure limits in work places. While in China, Canada and other countries have set occupational exposure limits (OEL) for FA; Nigeria, where FA usage is the mainstay in corpse preservation and anatomy laboratories, standard/occupational exposure limit is yet to be set by any of the Federal agencies responsible for monitoring and supervising the usage of chemicals. Legislation on the Use and Safety of

Exposure to Chemical Hazardous to Health beside Packaging & Labeling of Chemicals within the OSH Act – including routine Chemical Health Risk Assessment of factories and such - of a country which is regularly enforced by Inspection by officers of the Dept of OSH can bring about good control and prevention of hazards from such chemicals in the work-place.

4. CONCLUSION

FA concentration levels in private mortuaries are high compared to public mortuaries. The difference between FA concentration levels in the public and private mortuaries is highly significant. The concentration levels of FA observed in both the private and public mortuaries exceeded stipulated limits – thus, there is a high concentration of FA in the workplace of mortuaries in Rivers State particularly during the embalment process, this may significantly affect the exposed mortuary workers. Therefore, both short-term and long-term health effects are envisaged among the mortuary workers. There is epidemiologic evidences that exposure to FA is positively correlated with adverse health effects – therefore, FA pollution should be of greater health concern to both the government and operators of mortuaries in Rivers State.

5. RECOMMENDATION

The Federal Ministry of Labour and Productivity should use the findings of this study to inform management and mortuary workers in the State of the high levels of FA so that precautionary measures can be taken to reduce exposure periods. Mortuary owners should ensure that all workers are well protected against exposure to high levels of FA. Appropriate personal protective equipment (PPE) such as respirator-mask, apparel and apron, gloves, and work-boots should be provided for workers by management. Awareness and training programs for mortuary workers on safety of use of FA should be carried out regularly by operators of mortuaries. Public health department of the ministry of health should conduct regular Medical Assessment/Test or health surveillance on mortuary workers in the State for early symptoms of FA related diseases. National Environmental Standards and Regulations Enforcement Agency (NESREA) should carry out regular auditing of the mortuaries in the State. The Federal Ministry of Labour and Productivity should ensure that mortuaries in Nigeria are designed in compliance with relevant international standards, and ensure that mortuaries in the State are constructed with

good ventilation systems, local-exhaust ventilation and fume-cupboards.

ETHICAL APPROVAL

An approval letter to proceed with the study was obtained from the Center for Occupational Health, Safety and Environment (COHSE) of the University of Port Harcourt. The letter was presented to the mortuary operators seeking for their permission to carry out the monitoring, thus the consent of the mortuary proprietors was duly obtained. All mortuary proprietors were assured of maximum confidentiality and that information derived will be used mainly for research purposes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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