Comparative Analysis of Health Risk Associated with Occupational Exposure to Formaldehyde in Mortuaries in Rivers State, Nigeria

ABSTRACT

Background: Formaldehyde (FA) is a well-known chemical widely used in mortuaries in Nigeria for the preservation of human cadavers, yet little is known of the potential health risk associated with occupational exposure to formaldehyde in mortuaries. This study evaluated the potential health risk associated with occupational exposure to formaldehyde in mortuaries in Rivers State, Nigeria.

Methodology: The study was carried out in 7 public and 8 private mortuaries and the concentrations of formaldehyde to which the morticians are exposed were measured during the embalmment process. Modeling of health related risk was carried out in accordance with methods recommended by the United States Environmental Protection Agency (US EPA).

Results: The results showed that the lethal concentrations of formaldehyde in the mortuaries far exceeded the "No Significant Risk Levels" (LC_{50} = 3.3ppm for public mortuaries; and 3.46ppm for private mortuaries). Analysis showed that 77.2% of workers in the public mortuaries have high daily formaldehyde exposure index, while 88.24% of the workers in the private mortuaries have high daily formaldehyde exposure index. The difference between the formaldehyde daily exposure index and daily potential dose in public and private mortuaries was not statistically significant ($p > 0.05$). Computed hazard quotients for both public and private were 1.25 and 3.0 respectively (> 1). Computed cancer related risk values for public and private mortuaries were $1.5x10^{-3}$ and $1.9x10^{-3}$ respectively.

Conclusion: The study showed that embalmers in both the public and private mortuaries in Rivers State occupationally exposed to formaldehyde have significant risk of developing carcinogenic and non-carcinogenic related health problems. It is therefore, recommended that operators of mortuaries and Rivers State Government should provide FA monitoring device and continuous health education for workers.

Keywords: Formaldehyde; mortuaries; carcinogenic; non-carcinogenic.

INTRODUCTION

The health care system offers various services, including mortuary services, to the society (Kumar et al., 2016). Mortuaries receive corpses, embalmed/ preserved and finally deliver them to their respective owners (Okoth-Okello et al., 2013). These different processes involved in mortuary services expose the workers to occupational hazards with their associated health risks. A lot of hazards and health risk are associated with the operations of mortuaries. These hazards include exposure to hazardous chemicals and infectious diseases (Okoth-Okello et al., 2013). One of the occupational hazards associated with mortuary services include exposure to embalmment chemicals such as formaldehyde. Radiation risks, chemical risks and physical risks have been identified as occupational risks associated with the operations of mortuaries (Okoth-Okelloh et al., 2013; WorkSafe, 2013). Also, Kumar et al., (2016) in their study "Occupational Health and Safety Measures in a Mortuary of Private Tertiary Health Care Medical College

Hospital, Bangalore" identified chemical, physical and biological hazards that pose serious risk to mortuary workers.

Hazardous substances such as FA used in the mortuaries can enter the body by inhalation or through the skin contact (WorkSafe, 2010). Exposure to FA during embalmment is one of the occupational hazards that constitute risk to health and safety in the mortuary services. Continuous inhalation of FA can pose an adverse risk to the health of mortuary workers, or can also worsen their existing health problems (WorkSafe, 2010). The Occupational Safety and Health Administration (OSHA), National institute for occupational safety and health (NIOSH) and other regulatory bodies, including WHO have put formaldehyde exposure limits for workers at short times and at longer durations (WHO,2010). Scientific evidences, both in experimental animals and humans have shown that exceeding those exposure limits have some adverse health implications.

The risk associated with FA inhalation can be short-term or long-term risk or both. Acute or short-term health effects of FA exposure include eye and throat irritation and respiratory symptoms; while chronic or long-term health effects include chest tightness, cancers, swelling or spasms in the throat (glottis) and severe coughing (NCDOL, 2013). Continual and prolonged exposure to formaldehyde has been associated with lung and nasal passage cancers and myeloid leukemia in humans (USEPA, 1988; WHO, 1989, Hauptmann, M. et al, 2013). Short-term and long-term exposure to formaldehyde is highly irritating to the upper respiratory tract and can cause respiratory symptoms, throat, nose and eye and irritations (WHO, 1989; USDHHS, 1993). Oaklander (2015) reported that men, such as mortuary workers, who are exposed to high levels of formaldehyde, are at much greater risk of dying from Amyotrophic Lateral Sclerosis (ALS), otherwise called Lou Gehrig's disease. He stated further that morticians who are continuously exposed to high levels to formaldehyde are almost 4.5 times more likely to die from ALS than those who are not exposed to formaldehyde in their workplaces. Kumar et al., (2016) also reported that workers in mortuaries, particularly embalmers, are exposed to high concentration of formaldehyde which causes eye irritation and coughing.

In Nigeria, mortuaries services are provided by both the public sector (through government own hospitals) and the private sector. Douglas and Peterside (2016), in their study "Assessment of workplace hazards in mortuaries in Port Harcourt" identified formaldehyde exposure as one of the common hazards that constitute risk to the health of workers in mortuaries in Port Harcourt. Obed-Whyte, R. et al., (2019) in a study on "Comparative Assessment of Formaldehyde Concentrations in Public and Private Mortuaries in Rivers State, Nigeria" reported high concentrations of FA that far exceeded stipulated OSHA limit in some selected mortuaries in Rivers State, Nigeria. The study further stated that the high levels of FA obtained in mortuaries pose short-term and long-term risk to workers. The aim of this study is to analyze the health risk associated with occupational exposure to FA in mortuaries in Rivers State, Nigeria. This health risk analysis attempts to determine the short-term and long-term risk levels associated with exposure to FA in the mortuaries.

METHODOLOGY

The data used for this analysis is from a previous study conducted by the authors (Obed-Whyte, R. et al., 2019), hereafter referred to as paper 1. The study was carried out in 7 public mortuaries and 8 private mortuaries given a total of fifteen mortuaries as indicated in paper 1 (Obed-Whyte, R.et al., 2019). Concentrations of FA gas in the embalmment sections of the mortuaries were measured using a Globe Instrument, model PGas-20 CH_2O gas detector. The age, body weight, working time per day, and employment duration of the morticians were obtained and used for the health risk analysis. The health risk analysis presented in this paper is based on the United States Environmental Protection Agency Guidelines for Exposure Assessment (USEPA, 1992) and the United States Environmental Protection Agency Exposure Factors Handbook (USEPA, 1997). The study employed both semi-quantitative and qualitative risk assessment approach to determine health risk exposure to FA in mortuaries.

Determination of Lethal Concentration

The lethal concentration is the amount of formaldehyde concentration that proves fatal to the exposed mortuary workers**.** The values of formaldehyde concentrations and percentage of time it was equal to or exceeds the threshold limit were estimated using a linear regression technique presented in Equation (1).

$$LC_i = \alpha + \beta T_i \quad (1)$$

Where: LC_i is the formaldehyde concentration for a particular percentage of time (ppm), T_i is the percentage of time (%), α and β are coefficients of regressions.

The formaldehyde lethal concentrations for both the public and private mortuaries were computed by ranking the measured formaldehyde concentrations using the Weibull ranking approach. The corresponding lethal concentrations equal to or exceeded the threshold limit was determined and estimated from the plots of ranked observed concentrations versus the percentage of time exceeded or equal to threshold value**.** The lethal concentrations model was derived from the linear plots shown in Figures 3 and 4 as follows:

$$\mathrm{LT_x} = \alpha + \beta \ln(\mathrm{LC_x}) \quad (2)$$

Where: LT_x is the percentage of time exceeded that proof lethal, LC_x is the lethal concentration (ppm), α and β are constants.

Precisely, LC_x is the lethal concentration of the formaldehyde over which a mortuary worker is exposed for some period of time.

From the Equation (2), the lethal concentration is estimated as follows:

$$LC_x = Exp\left(\frac{LT_x - \alpha}{\beta}\right) \quad (3)$$

Semi-Quantitative Health Risk Assessment

The health risks associated with the exposure of morticians in both public and private mortuaries to formaldehyde were further assessed using a semi-quantitative approach (MOM, 2010; Beheshti et al., 2015; Heydari et al., 2016; Dazi et al., 2017). The exposure rate and risk rate were computed using Equations (4) and (5) respectively. The formaldehyde eexposure level (FEL) in the mortuaries was calculated using average measured concentrations of formaldehyde and the average duration each worker is exposed as well as the frequency of exposure as given in Equation (4) (MOM, 2010).

$$FEL = \frac{\text{EF x } \text{ED}_{\text{avg}} \text{ x } \text{C}_{\text{avg}}}{\text{W}_{\text{havg}}} \quad (4)$$

Where:
FEL = Formaldehyde Exposure level (ppm)
EF = Exposure frequency per week
ED_{avg} = average duration of each exposure (hours)
C_{avg} = average concentration (ppm)
W_{havg} = average working hours per week

The exposure rating (ER) was determined by comparing the formaldehyde exposure level (FEL) with the permissible exposure limit (PEL) as shown in Table 1.

Table 1: Exposure Rating of Formaldehyde

FEL/PEL	Exposure Rating (ER)
< 0.1	1
0.1 to < 0.5	2
0.5 to < 1.0	3
1.0 to < 2.0	4
≥ 2.0	5

Source: (MOM, 2010; Tang, 2016)

The exposure rating (shown in Table 1) are represented in an ordinal scale of 1 to 5 categorized in the order of severity of exposure, so that 1 indicates very low exposure, 2 indicates low exposure, 3 indicates moderate, 4 indicates high exposure and 5 indicates very high exposure (Heydari et al.,2016). The exposure indices were rated and the risk calculated using Equation (5) (Heydari et al., 2016; Tang, 2016; Dazi et al., 2017).

$$\text{Risk Rating} = \sqrt{\text{HR x ER}} \quad (5)$$

Where HR is the formaldehyde hazard rating and ER is the Exposure rating.
Formaldehyde hazard rating (HR) is given as 4 in MOM (2010) and Tang (2016).

The risk for each mortuary category was ranked as shown in Table 2 (Heydari et al., 2016) to determined levels of significance based on risk level of Table 1. (Tang, 2016),

Table 2: Risk Ranking Level of Formaldehyde

Risk Rating	Risk Ranking
1	Very low
2	Low
3	Moderate
4	High
5	Very high

Source: (Heydari et al., 2016)

Determination of Daily Exposure Index (DEI)

The Formaldehyde daily exposure index for each exposed worker in both the public and private mortuaries was computed using the average formaldehyde concentrations and the OSHA occupational exposure limit (OEL) of 0.75ppm as given in Equation 6. The formaldehyde daily exposure index was computed using Equation (4) modified from MOM, (2010) and Tang, (2016). The Daily exposure index is scaled such DEI less than 0.1 is considered as very low, DEI between 0.1 and 0.5 is considered as low, DEI between 0.5-1.0 is considered as moderate, DEI between 1.0 and 1.5 is considered as high, and DEI between 1.5 and 2.0 is considered as very high

$$DEI = \frac{\text{C x ET(hr)}}{\text{OEL} * 24\text{(hr)}} \qquad (6)$$

Where:

C = concentration (mg/m^3)

ET = exposure time (hr)

OEL = OSHA occupational exposure limit

Determination of Daily Potential Dose (DPD)

The Formaldehyde daily potential dose for each exposed worker in both the public and private mortuaries was computed using Equation 7.

$$DPD = \frac{\text{C x IR x ET(hr)}}{24\text{(hr)}} \qquad (7)$$

Where:

DPD = daily potential dose (mg/d)

C = average formaldehyde concentration (mg/m^3)

IR = the inhalation rate ($16m^3$/day)

ET = daily exposure time (hour)

An inhalation rate (IR) of $16m^3$/day was adopted in this study (USEPA, 2011)

Equations 4 and 5 assume that there is no exposure when embalmment is not carried out.

MODELING THE NON-CARCINOGENIC AND CARCINOGENIC RISK

Formaldehyde health risk assessment was carried out for non-cancer and cancer related risk. The modeling approach used in this study was adopted from the recommended method by the United States Environmental Protection Agency, US EPA (2011).

Modeling Non-Cancer Related Risk (NCRR)

Non-cancer related risk assessment is carried out to evaluate the short-term or acute health effects of formaldehyde exposure on mortuary workers. The average daily dose (ADD) and formaldehyde (Hazard) quotient (HQ) were used to evaluate the short-term non-carcinogenic effects of formaldehyde on the exposed morticians. The average daily dose (ADD) was used to evaluate different health effects other than cancer. It was computed by averaging the daily potential dose (DPD) over the body weights and the averaging time as shown Equation (8) (USEPA, 1997).

$$ADD = \frac{\text{Daily Potential Dose (DPD)}}{\text{Body Weight}} = \frac{\text{DPD(mg)}}{\text{BW(kg)}} \qquad (8)$$

Dose rate averaged over a pathway-specific period of exposure expressed as a daily dose on a per-unit-body-weight basis. The ADD is used for exposure to chemicals with non-carcinogenic or non-chronic effects (USEPA, 1997). The ADD unit is stated in terms of mass/mass-time or mg/kg/day.

Hazard quotient (HQ) method of risk characterization was also used to evaluate non-cancer risk of inhalational exposure to formaldehyde. The hazard quotient (HQ) was computed using Equation (9)

$$HQ = \frac{\text{Intake (mg/kg/d)}}{\text{Reference Dose (mg/kg/d)}}$$

$$HQ = \frac{\text{ADD (mg/kg/d)}}{\text{RfD (mg/kg/d)}} \qquad (9)$$

HQ less than 1.0 (HQ < 1.0) is within safe threshold, while HQ greater 1.0 (HQ > 1.0) is above safe threshold (USEPA, 1989). Reference Dose (RfD) is set up based on health risk assessments.

Modeling Cancer Related Risk (CRR)

The cancer related risk is computed using lifetime average daily doses (LADD). The USEPA (1997) recommended computing the long-term carcinogenic effects of formaldehyde using lifetime average daily dose (LADD). The LADDs for both the public and private mortuaries were computed using Equation (10).

Lifetime Average Daily Dose (LADD)

This is the dose rate averaged over a lifetime. The LADD is used to compute the carcinogenic or chronic effects of formaldehyde. The LADD unit is also stated in terms of mg/kg/day (USEPA, 1997).

$$LADD = \frac{\text{C x IR x ED}}{\text{BW x ALT}} \qquad (10)$$

Where:
C = formaldehyde concentration (mg/m^3)
IR = inhalation rate ($16m^3/day$)
ED = exposure duration (years)
BW = body weight (kg)
ALT = average lifetime (years)

Although the USEPA (1997) recommended that LADD be computed over a lifetime of 70 years, however, in this study, a life expectancy of 55 years for male gender in Nigeria as reported by WHO (2016) was used to compute LADD.

The Cancer related risk (CRR) associated with the inhalation of formaldehyde exposure was computed using the carcinogenic slope factor (CSF) according to EPA IRIS; Cal OEHHA (2018) as presented in Equation (11).

$$\text{Cancer Related Risk (CRR)} = \text{Intake (mg/kg/d) x carcinogenic slope factor (mg/kg/d)}^{-1}$$

$$CRR = LADD \text{ (mg/kg/day) x CSF (mg/kg/day)}^{-1} \quad (11)$$

The non-carcinogenic reference dose (RfD) and carcinogenic slope factor (CSF) are given by EPA IRIS; Cal OEHHA (2018) as 0.2 mg/kg/day and $0.021(mg/kg/day)^{-1}$ respectively.

Results and Discussion

The demographic characteristics of the mortuary workers in the public and private mortuaries are presented in Table 3. The average concentrations of formaldehyde obtained in public and private mortuaries are shown in Table 4. The values of the lethal concentrations for both the public and private mortuaries were estimated as shown in Table 5 and Figure 2. Plots of percentage of time the concentrations Equal to or exceeded Threshold concentration in public and private mortuaries are presented in Figures 3 and 4 respectively. Computed FA exposure and health risk ratings are presented in Table 6. The computed formaldehyde daily exposure indices for morticians in the mortuaries are shown in Table 7. The computed daily potential dose is shown in Table 8. The results of DEI and DPD normality test are presented in Figures 5 and 6 respectively. The variation of daily potential dose with time is presented in Figure 5.

Table 3: Demographic Characteristics of the Mortuary Workers

Characteristics	Public Mortuaries	Private Mortuaries
Average Age (years)	33	34.8
Average Employment duration (years)	7.5	5.4
Average Body weight (kg)	76.4	74.6
Average Working time (h/day)	8	10

The demographic characteristics of the mortuary workers in the public and private mortuaries (Table 1) showed that a mean age of 33years for public and 35ears for private mortuaries. Average length of exposures for workers public and private mortuaries are 7.5years and 5.4years respectively. Average body weights are 76kg and 74kg for public and private mortuaries respectively. Workers in the public mortuaries spent an average of 8 hours per day, while workers in the private mortuaries spent an average of 10 hours per day.

Table 4: Average Concentrations of Formaldehyde Measured in the Mortuaries

Mortuary Category	Minimum (ppm)	Maximum (ppm)	Mean (ppm)	Stdv. (ppm)	OSHA Limit
Public Mortuaries	0.0	8.25	2.42	1.77	0.75
Private Mortuaries	1.18	4.58	2.52	0.99	0.75

Stdv. = standard deviation. Source: Obed-Whyte, R. et al., (2019)

Results obtained from paper 1 (Obed-Whyte, R et al., 2019) presented in Table 4, showed that the average concentrations of formaldehyde obtained in public mortuaries varied between 0.0ppm and 8.25ppm with a mean of 2.42ppm; while concentrations obtained in private mortuaries varied between 1.18ppm and 4.58ppm with a mean of 2.52ppm.

The lethal concentrations of equations (1) and (2) were derived from the Figures 3 and 4 and the values of the lethal concentrations for both the public and private mortuaries were estimated as shown in Table 5 and Figure 2. These values far exceeded the "No Significant Risk Levels (NSRLs)" of 0.0326ppm or 40.0µg/m^3 (OEHHA, 2018).

Table 5: Computed Lethal Concentrations for Public and Private Mortuaries

	LC_{50} (ppm)	LC_{75} (ppm)	LC_{90} (ppm)	LC_{95} (ppm)	OSHA PEL
Public Morgues	3.3	2.81	2.51	2.41	0.75
Private Morgues	3.46	2.98	2.79	2.73	0.75

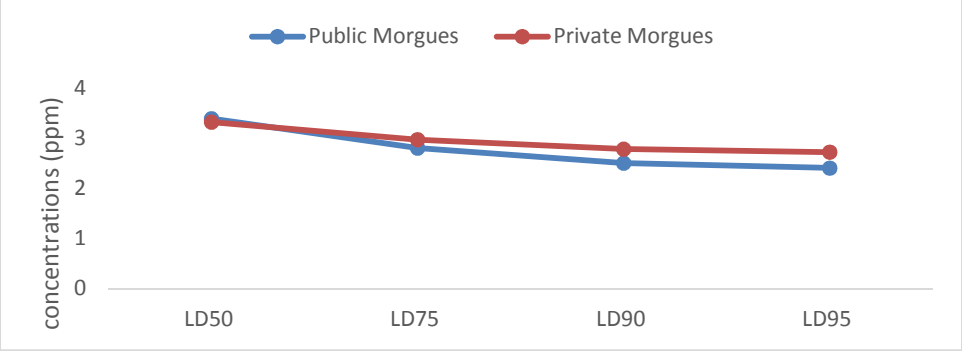

Figure 2: Computed Lethal Concentrations for both Public and Private Mortuaries

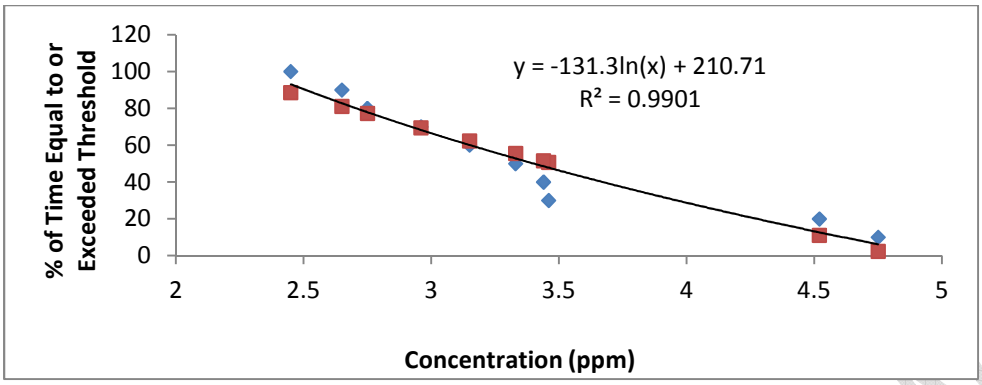

Figure 3: Percentage of Time Equal to or Exceeded Threshold versus concentrations in Public Mortuaries

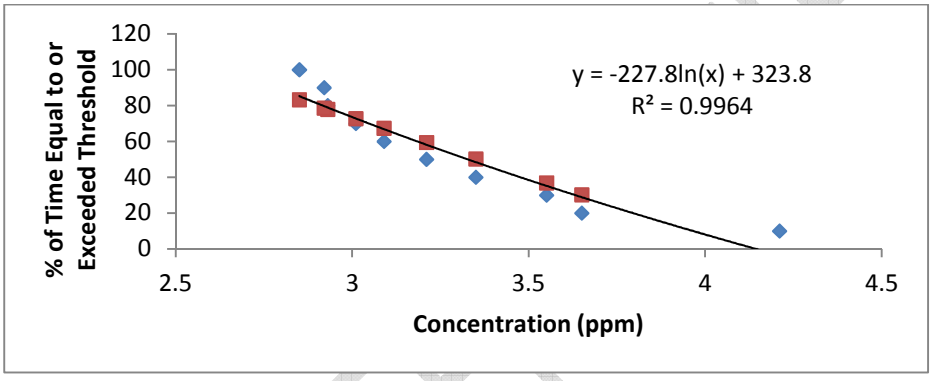

Figure 4: Percentage of Time Equal to or Exceeded Threshold versus concentrations in Private Mortuaries

Table 6: Computed Exposure and Health Risk Ratings

	Average Conc. (mg/m^3)	Exposure level (mg/m^3)	Exposure Rate (ER)	Risk Rating	Risk Ranking
Public Morgue	2.97	4.24	5	4.5	Very high
Private Morgue	3.09	2.49	5	4.5	Very high

An exposure rating of 5 was computed for both public and private mortuaries giving a risk rating of 4.5 and ranked as very high as shown in Table 6. This implies that the formaldehyde exposure in both public and private mortuaries in Rivers State poses very high health risk to morticians/embalmers.

Table 7: Computed Formaldehyde Daily Exposure Index

Public mortuaries (DEI)	Private mortuaries (DEI)
1.61	1.4
1.61	1.12
1.08	1.4
1.61	1.12
1.35	1.12
0.54	1.12
1.61	1.68
0.54	1.68
1.35	1.4
1.08	1.4
1.35	1.4
1.35	0.56
0.54	1.4
1.08	1.12
1.61	1.4
1.08	1.12
1.61	1.68
0.54	1.12
1.61	1.68
0.54	1.12
1.61	1.68
1.35	1.68

Normality test showed that DEI distribution in the mortuaries does not follow a normal distribution (Figure 5). The computed formaldehyde daily exposure index for morticians in public mortuaries ranged from 0.54 to 1.61 with a mean deviation of 1.21±0.42; while the computed DEI for embalmers in private mortuaries ranged from 0.56 to 1.68 with a mean deviation of 1.34±0.29. The result (Table 6.) showed that 40.9% of exposed morticians in the public mortuaries have daily exposure index between 1.5 and 2.0 rated as very high; 36.36% have DEI between 1.0 and 1.5 rated as high; while, 22.7% have DEI between 0.5and 1.0 rated as moderate. Similarly, computed daily exposure index showed that 23.53% of exposed morticians in private mortuaries have DEI between 1.5 and 2.0 rated as very high; 64.71% have DEI between 1.0 and 1.5 rated as high; while, 11.76% have DEI between 0.5-1.0 rated as moderate. Generally, 77.2% of workers in the public mortuaries have high daily formaldehyde exposure index, while 88.24% of the workers in the private mortuaries have high daily formaldehyde exposure index. The difference between the DEI in public and private mortuaries was not statistically significant ($p = 0.126$).

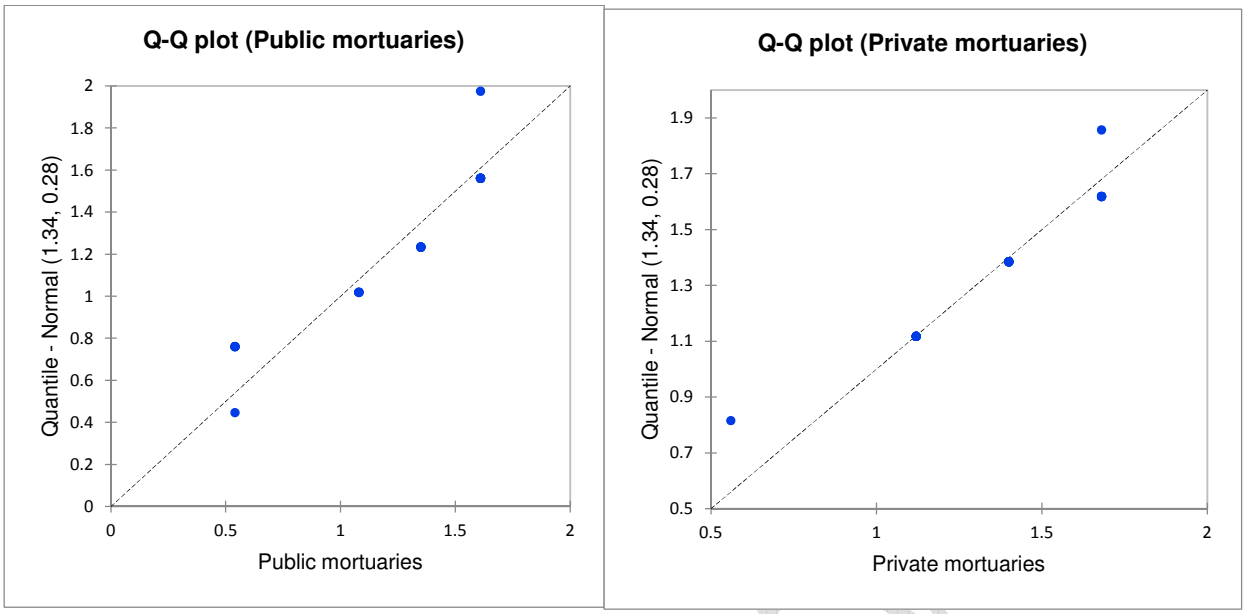

Figure 5: DEI Normal Q-Q plots of Normality Test

Table 8: Computed Daily Potential Dose

Public mortuaries (DPD, mg/d)	Private mortuaries (DPD, mg/d)
23.76	20.6
23.76	16.48
15.84	20.6
23.76	16.48
19.8	16.48
7.92	16.48
23.76	24.72
7.92	24.72
19.8	20.6
15.84	20.6
19.8	20.6
19.8	8.24
7.92	20.6
15.84	16.48
23.76	20.6
15.84	16.48
23.76	24.72
7.92	16.48
23.76	24.72
7.92	16.48
23.76	24.72
19.8	24.72

Normality test showed that DPD distribution in the mortuaries does not follow a normal distribution (Figure 6). The average formaldehyde concentrations, inhalation rate and the duration of exposure and the number of working hours per day were used to calculate the DPD. The results (Table 8) showed that daily potential dose in public mortuaries varies between 7.92mg/d and 23.76mg/d with a mean deviation of 17.82±6.2mg/d. Also, daily potential dose in private mortuaries varies between 8.24mg/d and 24.72mg/d with a mean deviation of 19.66±4.2mg/d. The difference between the DPD in public and private mortuaries is not statistically significant (p = 0.131). It is observed that daily potential dose increases with time of exposure (Figure 7). Lower daily doses were obtained during the 4-hour exposure, while higher daily doses were obtained during the 12-hour exposure. This showed that the longer the exposure period the higher the dose and hence the more the effects on the exposed workers. These levels of daily dose exposures have been found to cause acute health effects (ATSDR, 2010). Thus, the mortuary workers are in danger of adverse health effects from formaldehyde exposure.

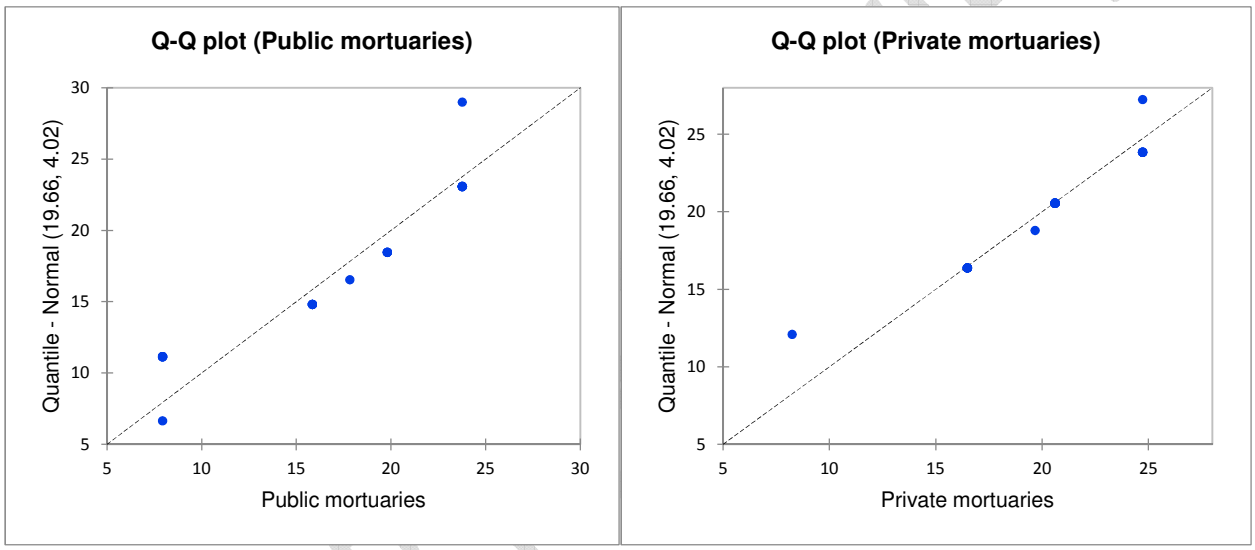

Figure 6: DPD Normal Q-Q plots of Normality Test

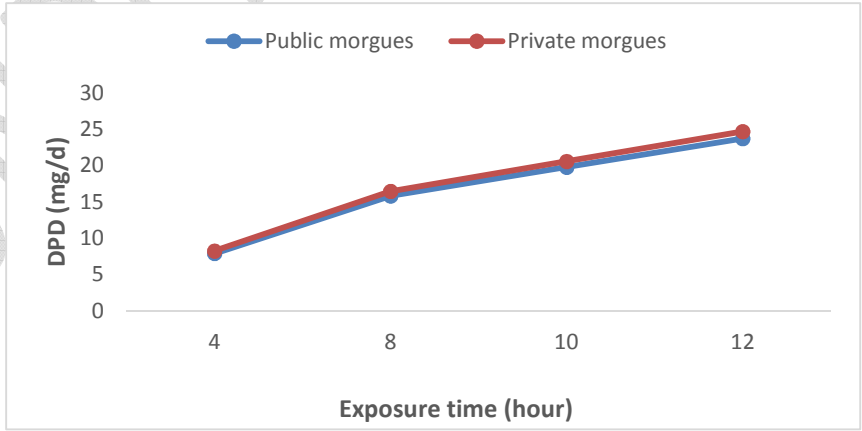

Figure 7: Computed Daily Potential Dose (DPD)

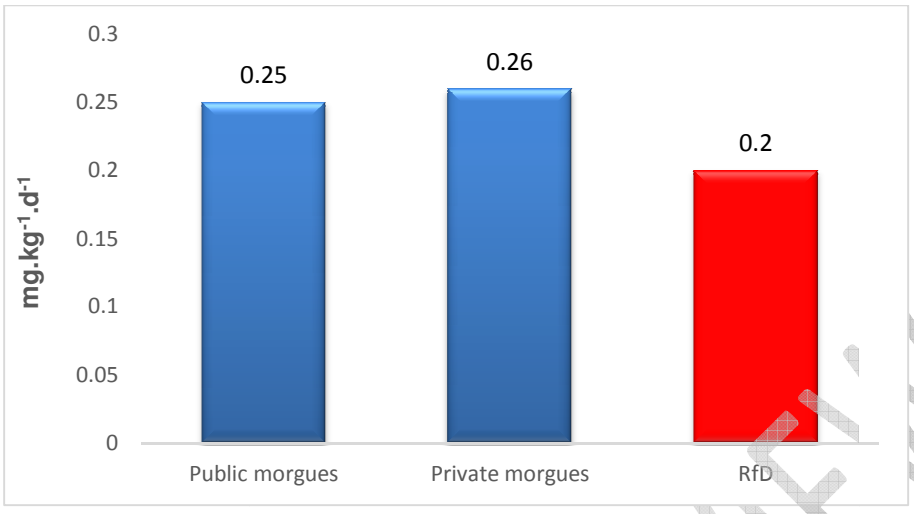

Figure 8: Mean Average Daily Doses for Public and Private Mortuaries

The computed average daily doses (ADD) for both the public and private mortuaries were compared with USEPA (1997) reference dose (RfD) of 0.2mg/kg/d. The computed average daily doses for public mortuaries ranged from 0.09 to 0.4mg/kg/d with a mean value of 0.25mg/kg/d (Figure 8), while the ADD values for private mortuaries ranged from 0.1 to 0.39mg/kg/d with a mean value of 0.26mg/kg/d (Figure 8). The ADD values for public and private mortuaries exceeded the reference dose by 25% and 30% respectively. These results revealed short-term or acute non-cancerous health effects associated with formaldehyde exposure among mortuary workers in both the public and private mortuaries in Rivers State. Computed hazard quotient for both public and private mortuaries are 1.25 and 3.0 respectively (Table 8). These values are greater than 1 (> 1) indicating that there is a considerable or significant non-cancer related risk of formaldehyde exposure in the mortuaries.

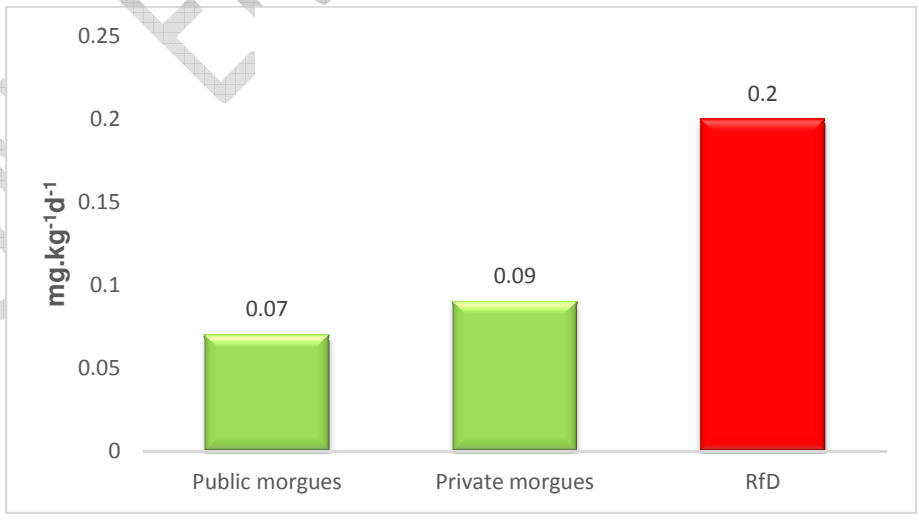

Figure 9: Mean Lifetime Average Daily Doses for Public and Private Morticians

Table 9: Computed Hazard Quotient

Mortuary Category	Mean ADD (mg/kg/d)	HQ
Public mortuaries	0.25	1.25
Private mortuaries	0.26	1.3

Table 10: Computed Cancer Related Risk

Mortuary Category	Mean LADD (mg/kg/d)	CRR	Safe threshold (USEPA 1989)
Public mortuaries	0.07	$1.5x10^{-3}$	$10^{-4} – 10^{-6}$
Private mortuaries	0.09	$1.9x10^{-3}$	

Computed LADD for public mortuaries ranged from 0.02mg/kg/d to 0.11mg/kg/d with a mean value of 0.07mg/kg/d (Figure 9), while computed LADD for private mortuaries ranged from 0.04 mg/kg/d to 0.17mg/kg/d with a mean value of 0.09mg/kg/d (Figure 9). The computed LADD values for both public and private mortuaries are within acceptable reference dose of 0.2mg/kg/d for formaldehyde exposure (USEPA, 1997). The computed cancer related risk values for public and private mortuaries are $1.5x10^{-3}$ and $1.9x10^{-3}$ respectively (Table 10). These values exceeded the threshold target range of 10^{-4} - 10^{-6} for cancer risk management (USEPA, 1989). Thus, the mortuary workers/morticians may be at significant cancer risk due to formaldehyde exposure in their workplace environment.

Previous studies had reported that chronic exposure to FA by male funeral directors revealed three times higher likelihood to die from Amyotrophic lateral sclerosis (ALS), i.e. Lou Gehrig's disease compared with FA unexposed population (Oaklander, 2015). Lou Gehrig's disease is a central nervous system (motor neurons) that causes nervous damage and can lead to impairment in movement, eating, talking, breathing and eventual death. Similarly, our present study has also showed that health effects are work duration dependent. The computed cancer related risk for both public and private mortuaries are high and far exceeded the threshold target of 10^{-4}-10^{-6} for cancer risk management (USEPA, 1989) and thus poses a significant cancer risk to morticians with over 20 years of service.

Some studies that evaluated the effects of FA when chronically exposed with high concentration of FA have reported that it causes increased prevalence of headache, depression, mood changes, insomnia, irritability, attention deficit and memory loss (ATSDR, 2010). Though, the International Agency for Research on Cancer (IARC) has classified FA as a human carcinogen (IARC, 2012); its use has not been banned yet. Aside, the CNS sequalae, it's been reported to have respiratory irritation effects that leads to chest pain, coughing and shortness of breath and asthma (ATSDR, 2010). These findings tend to support our earlier reports in our paper 1(Obed-Whyte et al, 2019).

The results of health risk analysis from this research corroborate with previous case control study among funeral industry workers who had died between 1960 and 1986. That study related cancer risk to duration of employment, work practices and estimated FA exposure levels in the funeral

industry and concluded that increased mortality/risk from myeloid leukemia was greatest among those who have worked as morticians for more than 20years (IARC,2012).

Conclusion: The study revealed that embalmers in both public and private mortuaries in Rivers State are exposed to high lethal concentrations and dose of formaldehyde use for the preservation of human cadavers. There is a considerable non-cancer and cancer related health risk due to the inhalation of formaldehyde exposure in the mortuaries. Analysis of short-term effect showed significant non-cancer health risk among the mortuary workers. Life-time risk analysis indicated significant carcinogenic health related risk among the mortuary workers. Thus cancer risks and non-cancer risks existed both in public and private mortuaries in the State. Therefore, occupational exposure to FA in mortuaries constitutes a significant health hazards in Rivers Sate, Nigeria.

Recommendation: Operators or owners of mortuaries should be informed of workplace FA hazards and risk face by the workers, particularly embalmers and take appropriate action to eliminate or minimize its exposure. The National Environmental Standards and Regulations Enforcement Agency (NESREA) should enact and enforce laws or guidelines on the use of FA in mortuaries in the State. The agency should advise mortuary proprietors to have FA measuring devices. Management of mortuaries in the State should be engaged the services of qualified and registered Assessors on Chemical Health Risk Assessment. The government of Rivers State should act quickly by setting up an assessment team to investigate FA pollution in all the mortuaries in the State as a way of intervention. Further studies is therefore recommended to help increase the index of association and help clarify our content analysis and hazard assessment of potential health risks related to formaldehyde occupational exposure

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