

1 **Comparative Analysis of Health Risk Associated with Occupational Exposure to**
2 **Formaldehyde in Public and Private Mortuaries in Rivers State, Nigeria**

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4
5 **ABSTRACT**

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

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

15 **Results:** The results showed that the lethal concentrations of formaldehyde in the mortuaries far
16 exceeded the “No Significant Risk Levels” ($LC_{50} = 3.3\text{ppm}$ for public mortuaries; and 3.46ppm
17 for private mortuaries). Analysis showed that 77.2% of workers in the public mortuaries have
18 high daily formaldehyde exposure index, while 88.24% of the workers in the private mortuaries
19 have high daily formaldehyde exposure index. The difference between the formaldehyde daily
20 exposure index and daily potential dose in public and private mortuaries was not statistically
21 significant ($p > 0.05$). Computed hazard quotients for both public and private were 1.25 and 3.0
22 respectively (> 1). Computed cancer related risk values for public and private mortuaries were
23 1.5×10^{-3} and 1.9×10^{-3} respectively.

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

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

30
31 **INTRODUCTION**

32 The health care system offers various services, including mortuary services, to the society [1].
33 Mortuaries receive corpses, embalmed/ preserved and finally deliver them to their respective
34 owners [2]. These different activities involved in mortuary services expose the workers to
35 occupational hazards with their associated health risks. A lot of hazards and health risk are
36 associated with the operations of mortuaries. These hazards include exposure to hazardous
37 chemicals (such as formaldehyde, paraformaldehyde glutaraldehyde and methanol) and
38 infectious diseases [2]. Physical, chemical and radiation risks have been identified as some of the
39 occupational health and safety (OHS) risks associated with the operations of mortuaries [2], [3].
40 Also, Kumar and his colleagues [1] in their study identified chemical, physical and biological
41 hazards that pose serious risk to mortuary workers.

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43 Hazardous substances such as FA used in the mortuaries can enter the body by inhalation or
44 through the skin contact [4]. Exposure to FA during embalmmment is one of the occupational
45 hazards in mortuary services as continuous inhalation of FA poses adverse risk to the health of
46 the morticians, or aggravates their existing health problems [4]. The Occupational Safety and
47 Health Administration (OSHA), National institute for occupational safety and health (NIOSH)
48 and other regulatory bodies and the World Health Organization (WHO) have put formaldehyde
49 exposure limits for workers at short times and at longer durations [5]. Scientific evidences, both
50 in experimental animals and humans have shown that exceeding these exposure limits have some
51 adverse health implications.

52 The risk associated with FA inhalation can be short-term or long-term risk or both. Acute or
53 short-term health effects of FA exposure include eye and throat irritation and respiratory
54 symptoms; while chronic or long-term health effects include chest tightness, cancers, swelling or
55 spasms in the throat (glottis) and severe coughing [6]. Continual and prolonged exposure to
56 formaldehyde has been associated with lung and nasal passage cancers and myeloid leukemia in
57 humans [7], [8], [9]). Short-term and long-term exposure to formaldehyde is highly irritating to
58 the upper respiratory tract and can cause respiratory symptoms, throat, nose and eye and
59 irritations [8], [10]. Oaklander [11] reported that men, such as mortuary workers, who are
60 exposed to high levels of formaldehyde, are at much greater risk of dying from Amyotrophic
61 Lateral Sclerosis (ALS), otherwise called Lou Gehrig's disease. He stated further that morticians
62 who are continuously exposed to high levels to formaldehyde are almost 4.5 times more likely to
63 die from ALS than those who are not exposed to formaldehyde in their workplaces. Kumar and
64 his colleagues [1] also reported that workers in mortuaries, particularly embalmers, are exposed
65 to high concentration of formaldehyde above 0.75ppm threshold limit resulting in eye irritation
66 and coughing.

67
68 In Nigeria, mortuary services are provided by both the public sector (through government own
69 hospitals) and the private sector. Douglas and Peterside [12], in their study "Assessment of
70 workplace hazards in mortuaries in Port Harcourt" identified formaldehyde exposure as one of
71 the common hazards that constitute risk to the health of workers in mortuaries in Port Harcourt.
72 Obed-Whyte and his colleagues [13] in a study on "Comparative Assessment of Formaldehyde
73 Concentrations in Public and Private Mortuaries in Rivers State, Nigeria" reported high
74 concentrations of FA that far exceeded stipulated OSHA limit in some selected mortuaries in
75 Rivers State, Nigeria. The study further stated that the high levels of FA obtained in mortuaries
76 pose short-term and long-term risk to workers. The aim of this study is to carry out a
77 comparative analysis of the health risks associated with occupational exposure to FA in public
78 and private mortuaries in Rivers State, Nigeria. This study attempts to determine the short-term
79 and long-term risk levels associated with exposure to FA in public and private mortuaries.

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METHODOLOGY

The study was carried out in 7 public mortuaries and 8 private mortuaries given a total of fifteen mortuaries as indicated. Concentrations of FA gas in the embalment sections of the mortuaries were measured using a Globe Instrument, model PGas-20 CH₂O gas detector [Obed-Whyte and his colleagues] [13]. The age, body weight, working time per day, and employment duration of the morticians were obtained and used for the health risk analysis. The study employed both semi-quantitative and quantitative risk assessment approach to determine health risk exposure to FA in mortuaries. The semi-quantitative risk assessment was based on the hazards rating and ranking of FA [14] and [15]. The quantitative risk assessment approach uses mainly mathematical relationships between variables based on the United States Environmental Protection Agency Guidelines for Exposure Assessment [16] and the United States Environmental Protection Agency Exposure Factors [17].

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Data analysis was carried out using Microsoft Excel. Mean and standard deviation were computed and data were presented in either tables or graphs. The levels of significance in the formaldehyde daily exposure index (DEI) and daily potential dose (DPD) between public and private mortuaries were determined using analysis of variance (ANOVA) in Microsoft Excel

Determination of Lethal Concentration

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 in part per million (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 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:

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

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.

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

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

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 [14], [18], [19], [20]. The exposure rate and risk rate were computed using Equations (4) and (5) respectively. The formaldehyde exposure level (FEL) in the mortuaries was calculated using average concentrations of formaldehyde and the average duration each worker is exposed as well as the frequency of exposure as given in Equation (4) [14].

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$$FEL = \frac{EF \times ED_{\text{avg}} \times C_{\text{avg}}}{W_{\text{havg}}} \quad (4)$$

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: [14], [15]

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 [19]. The exposure indices were rated and the risk calculated using Equation (5) [19], [15], [20].

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

Where HR is the formaldehyde hazard rating and ER is the Exposure rating.

Formaldehyde hazard rating (HR) is given as 4 in [14] and [15].

The risk for each mortuary category was ranked to determined levels of significance based on risk level shown in Table 1 [15] and risk ranking shown in Table 2 [19]).

Table 2: Risk Ranking Level of Formaldehyde

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

Source: [19]

Quantitative Health Risk Assessment

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 [17]. The formaldehyde daily exposure index was computed using Equation (4) modified from [14] and [15]. 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

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$$DEI = \frac{C \times ET(hr)}{OEL \times 24(hr)} \quad (6)$$

Where:

C = concentration (mg/m³)
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.

$$DPD = \frac{C \times IR \times ET(hr)}{24(hr)} \quad (7)$$

Where:

DPD = daily potential dose (mg/d)
C = average formaldehyde concentration (mg/m³)
IR = the inhalation rate (16m³/day)
ET = daily exposure time (hour)

An inhalation rate (IR) of 16m³/day was adopted in this study [21]

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

186 MODELING THE NON-CARCINOGENIC AND CARCINOGENIC RISK

187 Formaldehyde health risk assessment was carried out for non-cancer and cancer related risk. The
188 modeling approach used in this study was adopted from the recommended method by the United
189 States Environmental Protection Agency [21].

190 Modeling Non-Cancer Related Risk (NCRR)

191 Non-cancer related risk assessment is carried out to evaluate the short-term or acute health
192 effects of formaldehyde exposure on mortuary workers. The average daily dose (ADD) and
193 formaldehyde (Hazard) quotient (HQ) were used to evaluate the short-term non-carcinogenic
194 effects of formaldehyde on the exposed morticians. The average daily dose (ADD) was used to
195 evaluate different health effects other than cancer. It was computed by averaging the daily
196 potential dose (DPD) over the body weights and the averaging time as shown Equation (8) [17].
197

$$198 \quad ADD = \frac{\text{Daily Potential Dose (DPD)}}{\text{Body Weight}} = \frac{DPD(\text{mg})}{BW(\text{kg})} \quad (8)$$

199 Dose rate averaged over a pathway-specific period of exposure expressed as a daily dose on a
200 per-unit-body-weight basis. The ADD is used for exposure to chemicals with non-carcinogenic
201 or non-chronic effects [17]. The ADD unit is stated in terms of mass/mass-time or mg/kg/day.
202

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

$$206 \quad HQ = \frac{\text{Intake (mg/kg/d)}}{\text{Reference Dose (mg/kg/d)}}$$

$$207 \quad HQ = \frac{ADD (\text{mg/kg/d})}{RfD (\text{mg/kg/d})} \quad (9)$$

208 HQ less than 1.0 ($HQ < 1.0$) is within safe threshold, while HQ greater 1.0 ($HQ > 1.0$) is above
209 safe threshold [22]. Reference Dose (RfD) is set up based on health risk assessments.

210

211 Modeling Cancer Related Risk (CRR)

212 The cancer related risk is computed using lifetime average daily doses (LADD). The USEPA
213 (1997)[16] recommended computing the long-term carcinogenic effects of formaldehyde using
214 lifetime average daily dose (LADD). The LADDs for both the public and private mortuaries
215 were computed using Equation (10).

216 Lifetime Average Daily Dose (LADD)

217 This is the dose rate averaged over a lifetime. The LADD is used to compute the carcinogenic or
218 chronic effects of formaldehyde. The LADD unit is also stated in terms of mg/kg/day [17].

$$219 \quad LADD = \frac{C \times IR \times ED}{BW \times ALT} \quad (10)$$

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Where:

C = formaldehyde concentration (mg/m³)

IR = inhalation rate (16m³/day)

ED = exposure duration (years)

BW = body weight (kg)

ALT = average lifetime (years)

Although the [17] 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 [National Bureau of Statistics](#) [23] 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 Cal [OEHHA](#) [24] as presented in Equation (11).

Cancer Related Risk (CRR) = Intake (mg/kg/d) x carcinogenic slope factor (mg/kg/d)⁻¹

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

The non-carcinogenic reference dose (RfD) and carcinogenic slope factor (CSF) are given by [EPA IRIS; Cal OEHHA \(2018\)](#) [23] as 0.2 mg/kg/day and 0.021(mg/kg/day)⁻¹ respectively.

Results

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. Plots of percentage of time the concentrations Equal to or exceeded Threshold concentration in public and private mortuaries are presented in Figures 2 and 3 respectively. Result of semi-quantitative health risk analysis in public and private mortuaries is 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 4 and 5 respectively. The variation of daily potential dose with time is presented in Figure 6.

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

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Table 4: Average Concentrations of Formaldehyde 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.

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

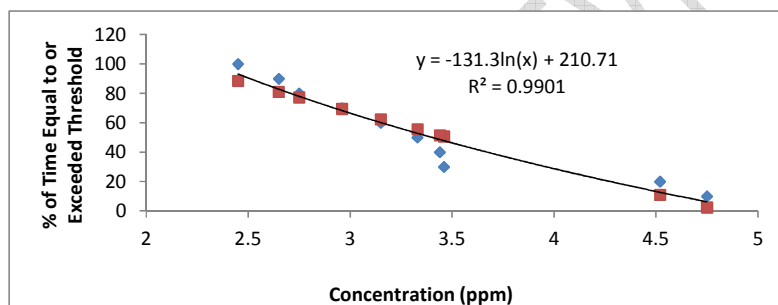


Figure 2: Percentage of Time Equal to or Exceeded Threshold versus concentrations in Public Mortuaries

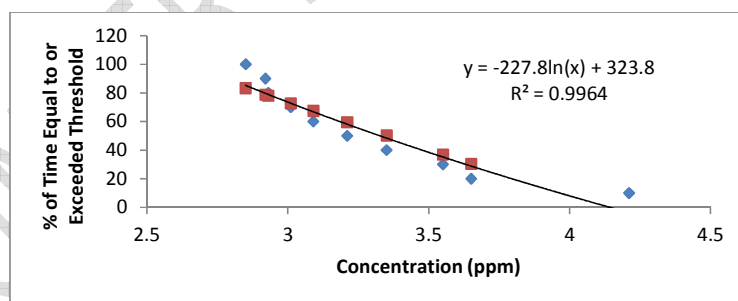


Figure 3: Percentage of Time Equal to or Exceeded Threshold versus concentrations in Private Mortuaries

Table 6: Result of Semi-quantitative Health Risk Analysis

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

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

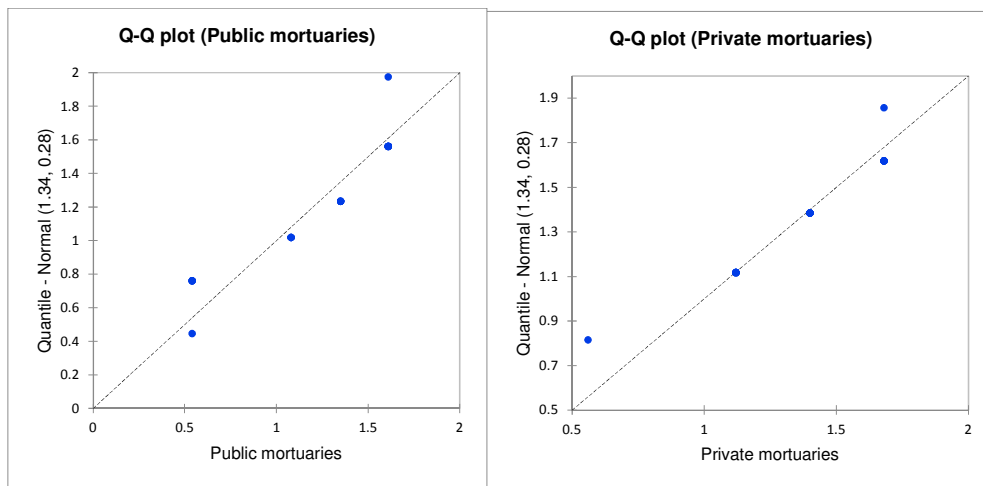


Figure 4: DEI Normal Q-Q plots of Normality Test

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

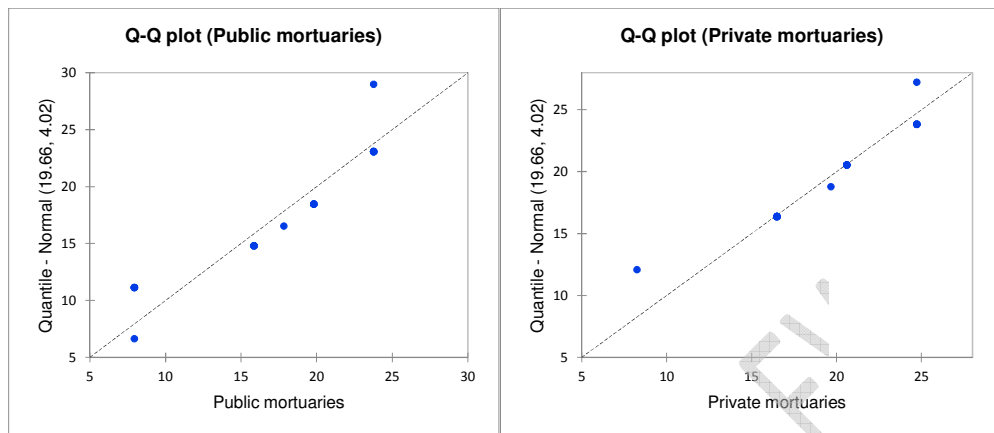


Figure 5: DPD Normal Q-Q plots of Normality Test

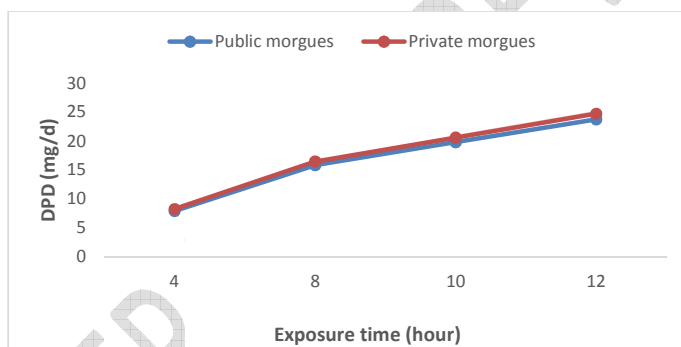


Figure 6: Computed Daily Potential Dose (DPD)

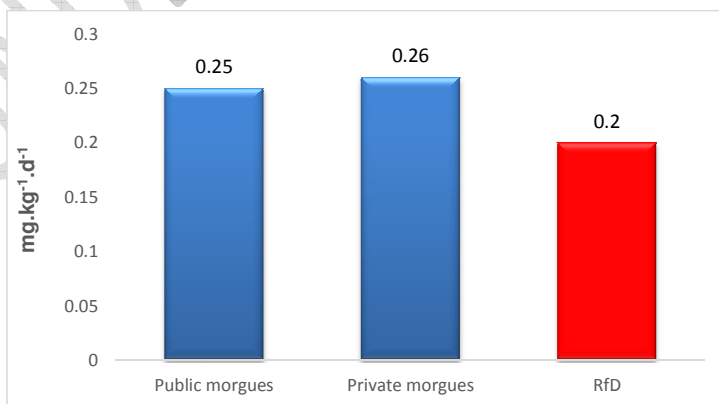


Figure 7: Mean Average Daily Doses for Public and Private Mortuaries

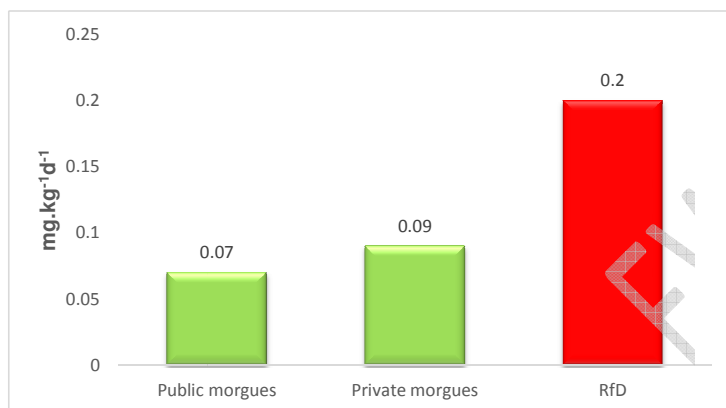


Figure 8: Mean Lifetime Average Daily Doses for Public and Private Morticians

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 [22]
Public mortuaries	0.07	1.5×10^{-3}	$10^{-4} - 10^{-6}$
Private mortuaries	0.09	1.9×10^{-3}	

Discussion

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 35years 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. Results (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

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Table 5. These values far exceeded the “No Significant Risk Levels (NSRLs)” of 0.0326ppm or 40.0µg/m³ [24].

Semi-quantitative analysis shows an exposure rating of 5 for both public and private mortuaries, this gives a risk rating of 4.5 which is ranked as very high as shown in Table 6. Similar result was obtained by Douglas and Peterside [12]. This implies that the formaldehyde exposure in both public and private mortuaries in Rivers State poses very high health risk to morticians/embalmers.

Normality test showed that DEI distribution in the mortuaries does not follow a normal distribution (Figure 4). 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 and standard deviation of 1.34±0.29. The result (Table 7) 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 0.5 and 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. Analysis of variance indicates that the difference between the DEI in public and private mortuaries was not statistically significant (p = 0.126; 95%CI).

Normality test also showed that DPD distribution in the mortuaries does not follow a normal distribution (Figure 5). 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 and standard 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 and standard deviation of 19.66±4.2mg/d. Analysis of variance indicates that the difference between the DPD in public and private mortuaries was not statistically significant (p = 0.131; 95%CI). It is observed that daily potential dose increases with time of exposure (Figure 6). 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 [25]. Thus, morticians in Rivers State are in danger of adverse health effects due to formaldehyde exposure as also reported by Olooto [26] and Douglas and Peterside [12].

The computed average daily doses (ADD) for both the public and private mortuaries were compared with [17] 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 7), 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 7). 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 the mortuary workers in

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348 both the public and private mortuaries in Rivers State. Computed hazard quotient for both public
349 and private mortuaries are 1.25 and 3.0 respectively (Table 8). These values are greater than 1 (>
350 1) indicating that there is a considerable or significant non-cancer related risk of formaldehyde
351 exposure in the mortuaries.

352 Computed LADD for public mortuaries ranged from 0.02mg/kg/d to 0.11mg/kg/d with a mean
353 value of 0.07mg/kg/d (Figure 8), while computed LADD for private mortuaries ranged from 0.04
354 mg/kg/d to 0.17mg/kg/d with a mean value of 0.09mg/kg/d (Figure 8). The computed LADD
355 values for both public and private mortuaries are within acceptable reference dose of 0.2mg/kg/d
356 for formaldehyde exposure (USEPA, 1997). The computed cancer related risk values for public
357 and private mortuaries are 1.5×10^{-3} and 1.9×10^{-3} respectively (Table 10). These values exceeded
358 the threshold target range of 10^{-4} - 10^{-6} for cancer risk management [22]. Thus, the mortuary
359 workers/morticians may be at significant cancer risk due to formaldehyde exposure in their
360 workplace environment. The morticians could develop cancer such as nasal cavity, and
361 nasopharynx, later in life after retirement from service. Olooto [26] reported that formaldehyde
362 exposure causes the impairment of the synthetic function of the liver of mortuary workers in
363 Nigeria and also significantly reduced their total globulin level resulting in increased risk of
364 suppressed humoral immunity. However, Checkoway and his colleagues [27] in their study
365 found no association between associations between formaldehyde and either Hodgkin leukemia
366 or chronic myeloid leukemia,

367
368 Previous studies had reported that chronic exposure to FA by male funeral directors revealed
369 three times higher likelihood to die from Amyotrophic lateral sclerosis (ALS), i.e. Lou Gehrig's
370 disease compared with FA unexposed population [11]. Lou Gehrig's disease is a central nervous
371 system (motor neurons) that causes nervous damage and can lead to impairment in movement,
372 eating, talking, breathing and eventual death. Similarly, our present study has also showed that
373 health effects are work duration dependent. The computed cancer related risk for both public and
374 private mortuaries are high and far exceeded the threshold target of 10^{-4} - 10^{-6} for cancer risk
375 management [22] and thus poses a significant cancer risk to morticians with over 20 years of
376 service.

377
378 Some studies that evaluated the effects of FA when chronically exposed with high concentration
379 of FA have reported that it causes increased prevalence of headache, depression, mood changes,
380 insomnia, irritability, attention deficit and memory loss [25]. Though, the International Agency
381 for Research on Cancer (IARC) has classified FA as a human carcinogen [28]; its use has not
382 been banned yet. Aside, the CNS sequelae, it's been reported to have respiratory irritation effects
383 that leads to chest pain, coughing and shortness of breath and asthma [15]. These findings
384 corroborated earlier finding by Obed-Whyte and his colleagues [13].

385
386 The results of health risk analysis from this research corroborate with previous case control study
387 among funeral industry workers who had died between 1960 and 1986. That study related cancer
388 risk to duration of employment, work practices and estimated FA exposure levels in the funeral
389 industry and concluded that increased mortality/risk from myeloid leukemia was greatest among
390 those who have worked as morticians for more than 20 years [26].

391 **Conclusion:** The study revealed that embalmers in both public and private mortuaries in Rivers
392 State are exposed to high lethal concentrations and dose of formaldehyde use for the preservation

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393 of human cadavers. Results of both semi-quantitative and quantitative analysis indicate very high
394 risk of FA exposure in both public and private mortuaries. The study shows a considerable non-
395 cancer and cancer related health risks in the mortuaries due to the inhalation of formaldehyde
396 gas. Analysis of short-term effect showed significant non-cancer health risk among the mortuary
397 workers. Life-time risk analysis indicated significant carcinogenic health related risk among the
398 mortuary workers. Thus cancer risks and non-cancer risks existed both in public and private
399 mortuaries in the State. Therefore, occupational exposure to FA in mortuaries constitutes a
400 significant health hazards in Rivers Sate, Nigeria.

401 **Recommendation:** Occupational and public health workers should create awareness among
402 mortuaries operators/owners in Rivers State on the health risk **face** by the morticians, particularly
403 embalmers so that appropriate action can be taken to minimize exposure to FA. Regular
404 monitoring of FA in all the mortuaries in the State should be carried out by the National
405 Environmental Standards and Regulations Enforcement Agency (NESREA). The Agency should
406 also enact and enforce laws or guidelines on the use of FA in mortuaries in the State.

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407 Management of mortuaries in the State should **be engaged** the services of qualified and registered
408 assessors on Chemical Health Risk **Assessment** to conduct health surveillance on the exposed
409 mortuary workers.

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410 Further studies are therefore recommended to help increase the index of association and help
411 clarify the content analysis of this study and also assess FA effect on the male fertility level of
412 the exposed morticians

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