

The Tripod Relationship Between Local Embalment, Environment and Human Health Implications in Cross River State, Nigeria

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Abstract

The purpose of this paper is to assess the environmental and health implications of local embalment in Cross River State, Nigeria. The Ex-post-facto research design was adopted for this study. Six embalment sites from six Local Government Areas were randomly selected across the state from where water and soil samples were taken for laboratory analysis and testing. The environmental impacts, as well as the health implications of local embalment, were investigated. Multivariate statistical analysis was applied for the physicochemical parameters using a correlation matrix to evaluate factors influencing the groundwater chemistry and sources of pollution in the aquifer of the areas. Some laboratory procedures were also adopted to test the chemistry of the adjoining soils for the impacts of these embalment chemicals as used by these morticians. A comparative analysis was further done on the different soil samples, the ones directly affected by the immediate mortuary facilities and those away from the facilities. A structured questionnaire made up of twenty items was also administered to the mortuary attendants and residents of the communities and adjoining communities where these embalment homes are located. Simple percentage and correlation analysis was done to examine the perceived effect of embalment chemicals on the environment and the health of residents. The results obtained from the laboratory analyses of selected groundwater and soil samples around the mortuary sites studied indicated that formaldehyde, glutaraldehyde, humectants, metals, coli forms, microorganisms, and other contaminants from the mortuary sites have impaired the soil and water quality. It was recommended among others that green embalment procedures should be encouraged, embalment services should be located far away from residential areas and water bodies; wastes from embalment/mortuary services should be sustainably disposed of to avoid these chemicals from contaminating the environment.

Keywords: Embalment; Formaldehyde; Glutaraldehyde; Environmental and human health; Water and soil quality.

1. Introduction

The word embalment can be defined as a process where biological organisms which are decomposable are prevented from decaying or undergoing biological decomposition through the use of different methods, especially the use of organic or inorganic chemicals to preserve them from decaying or decomposition. To embalm means to preserve (cadaver or corpse) from decaying, originally with spices and now usually by arterial injections of different preservatives. The embalment of corpses in recent times has become a normal routine in homes, hospitals and in some places a local repository built by untrained or non-professional persons for the purpose of making money. Doing this in a place that was not originally meant to keep and embalm corpses comes with some social, environmental and health concerns, [1]. The main trust of this paper is then to examine how these chemicals used for local embalment has affected the soils, water, health and environmental conditions of the affected areas.

According to Huang, *et al.* [2], embalming is the art and science of preserving human or animal remains by treating them to forestall decomposition. The intention is usually to make the deceased suitable for public or private viewing as part of the funeral ceremony, or keep them preserved for medical purposes in an anatomical laboratory. In professional embalment practices, every embalment begins with the process of washing the corpse with disinfectant solution; this is followed by massaging and manipulating the limbs to allow for flexibility and relieving rigor mortis i.e. stiffening of the joints and muscles. This is followed by shaving off the facial hair, except in situation where the person died wearing the facial hair. After all these processes have been done, then the mortician proceeds with the surgical operations to remove the bodily fluid and replaced with formaldehydes- based chemical solutions. This is then followed by cosmetic process, preparing the corpse for public viewing [3, 4].

Generally speaking, there are two types of corpse embalment: the arterial embalment and cavity embalment. In arterial embalment, the blood is removed through the veins and replaced with embalment solutions through the arteries. The embalment solution is usually a combination of formaldehyde, glutaraldehydes, methanol, ethanol, phenol, humectants, water and dyes to simulate a life-like skin tone. In modern mortuary facilities, wetting agents, and other solvents can be used. The formaldehyde content generally ranges from 5 to 35 percent, and the ethanol content may range from 9 to 56 percent. In cavity embalming, this is done by making a sharp incision near the belly button using a very sharp surgical instrument, the incised placed is then inserted with a trocar into the cavity. Organs in the chest cavity are punctured of gas and drained of fluid contents; this is then replaced with the embalment solution containing formaldehyde-based chemical mixtures. After which the incision is closed using any method of suture, the part of the body where the incision is made is then heavily and fully embalmed [4-6].

In all these, those engaged in the local embalment practices, do neither of these two, they just go straight into injecting the formaldehyde and other chemicals used for the embalment into the major places where they believe that decaying and decomposition takes place, the head, the abdomen, the legs and the thoracic regions. When this process is done with, the remaining chemical used for embalment are poured into the water used in bathing/washing the corpse, then poured into the surrounding or into a hole dug in the ground. A lot of scholars have found a significant influence of waste from embalment activities and the contamination of adjoining soils and water around such environment. The lead (Pb) components affect the liver, kidney and the heart of human beings, just like it affects the lungs of the environment [6-9].

Environmentalists generally disapprove of embalming because of the harmful chemicals involved and their interactions with the environment. Recently, eco-friendlier embalming methods have become available in modern climes, but same cannot be said of the local embalment done in Nigeria. Most often than not, local embalment is carried out using chemicals with lethal effects on the environment, water, air, land and human health. Most often, chemicals used for local emblems contain lead, cyanide and other toxic chemicals. These chemical combine with some naturally occurring compounds in the soil, their reactive combinations are capable of causing harm to human health and environmental degradation [10, 11].

Various studies have shown that when the embalmed corpse is buried and decaying process begins, the fluid can seep into the adjoining soils and water, affecting the ecosystems around the area. Majorly, the chemicals used for embalment of corpse is made up of about 5% formaldehyde into the blood vessels of the corpse, while the fluid or solution injected into the body of the corpse is made up of between 35-45% of lethal chemicals. Studies have shown that embalming fluid acts to denature cellular proteins, thereby making deficit nutrient sources for bacteria; furthermore, these embalment fluids kill decomposing bacteria themselves. Formaldehyde or glutaraldehyde fixes tissue or cells by irreversibly connecting a primary amine group in a protein molecule with nearby nitrogen in a protein or deoxyribonucleic acids (DNA) molecule through a $-CH_2-$ linkage called a Schiff base. The end result also creates the simulation, via color changes, of the appearance of blood flowing under the skin, [12, 13].

Brenner [14], listed the following as some embalment chemicals popularly used by embalment experts: Glyoxal (oxaldehyde), Glutaraldehyde, formaldehyde, Phosphonium chloride (Tetrakis or hydroxymethyl), Sodium nitrate, Methyl-3-octyloxymethylimidazolium, Sodium borate (Boric acid), tetrafluoroborate and Phenoxyethanol. These chemicals have various effects on both human and environmental health. These chemicals have various roles in to play from preventing decay, softening of tissues, clothing of and dryness of blood and the cooling to the preservation of the corps from decomposition. The severity and lethality of these chemical compounds depends on the chemical reaction it has with some chemicals in the environment and the other components used by the embalmer, [3, 15, 16]. Example, an estimated 10-20 million liters of embalment chemicals of different chemical compositions are used annually for embalment, out of which about 55-85% of this amount are used locally, mostly by ill trained quacks that sees profit in the business of corpse preservation in most rural communities. Studies have shown that formaldehyde stiffen the corpse tissues, thereby allowing the embalmer to keep the corpse erect. This is the characteristic that also makes formaldehyde hazardous when it interacts with the environment. When there is an encounter with the environment, the hydrogen atoms in the environment combines with the carbon atom in formaldehyde, CH_2O , which carries a slightly positive charge due to the high electronegative atom of oxygen, this double bond with the carbon. The electropositive carbon will react with a negatively charged molecule and other electron-rich species. As a result, the carbon in the formaldehyde molecule bonds with electron-rich nitrogen groups called amines found in plant and animal tissue. This leads to formaldehyde cross-linking, bonding proteins with other proteins and DNA, making them to be dysfunctional and become useless or no longer useful to human in nature, [12, 13, 17].

Martin [15], found that because of the harmful effects of formaldehyde, which is used as an embalment chemical, this chemical is listed as one of the top ten most dangerous chemicals in the United States (US)

Environmental Protection Agency's list of the most damaging agent of the environment. Formaldehyde by nature are carcinogenic compounds in humans and animals. This is because the cross-linking or bonding between carbon, hydrogen and oxygen atoms when encountered with the environment can cause DNA to keep cells from halting the replication process and renders them useless. This unwarranted replication of cells can lead to cancer. Shea [18] found with regrets that unicellular organisms found in the soil and groundwater are also quite sensitive to cross-linking, they experience damage at a concentration of 0.3 mg to 22 mg per liter. Formaldehyde also affects aquatic invertebrates, with crustaceans being the most sensitive type. The range of concentration damaging them is estimated at about 0.4 mg to 20 mg per liter. Studies have also shown that formaldehyde has been known to injure some marine plant life and kill the root systems of some small plants, [13, 15, 18].

Taking a further look at the effects of embalment fluid on human health, Dixit, *et al.* [19] found that vapors emanating from embalment fluid in the dissection rooms are a perennial cause of irritation to the eye, the mucous membranes of the pharynx, the upper respiratory tract and the mucosal lining of the throat and nostrils. The authors further said, embalment fluids are poisonous to the skin on repeated contact with the skin [12, 13].

However, due to the public outcry on the growing awareness of the negative effects of embalming fluid on the environment and human health, people have become concerned to consider green burials, where there are either no harsh chemicals used in the embalming process, or there is no embalming process at all [15, 17]. For those who still want embalment in the United States, the Champion Company created Enigma has been used as a replacement for previous embalment fluid. This embalming fluid (enigma) is organic and can be used, if a family insists on embalment, thus green embalment fluid like enigma is approved by the Green Burial Association of America. It is worrisome how the use of local embalment has increased in recent times and what are the effect these chemicals have on the environment and human health? It is on the strength of this submission that this research is designed to assess the environmental and health implications of local embalment in Cross River State, Nigeria.

The purpose of the study is to:

1. Examine the environmental implications of local embalment in Cross River State, Nigeria
2. To investigate the health implications of local embalment in Cross River State, Nigeria.

Two commensurate research questions were generated to help direct this research thus:

1. What are the environmental implications of local embalment (soil and water)?
2. How does local embalment affect human health?

2. Materials and Methods

2.1. Study Area

Cross River State is one of the 36 states in Nigeria, located in the South-South Geo-political zone of the country. Cross River State lies between Latitude 5°45' and 5.750° north of the Equator and Longitude 8°30' and 8.500° East of the Greenwich Meridian. The state has an estimated landmass of about 20, 156Km² with a projected population of about 3.938 million (Google Population projection, 2021). The vegetation of the state is the tropical rainforest, which progresses into the lower part of the state becoming grassland savannah. Cross River state has a tropical climate characterized by a single tropical rainy season. Rain falls from March to November with peaks in June- July and September.

Annual rainfall is generally high throughout the sector decreasing from 3000mm in the south to 2500mm in the northern extremities. Ambient temperatures are high but lower temperatures of about 14°C -16°C daily minima, and 18°C -25°C daily maxima are recorded on the highland areas of Obudu plateau and Sankwala Mountains [17, 20]. The influence of the relief from the ridge from Sao Tome, Fernada Po, Principe and Equatorial Guinea along the ridge through to Obudu mountains have some influence on rainfall pattern particularly in the southern and northern part of the state. Daytime temperature may reach 35°C -42°C in the dry season and as low as 25°C -32°C in the rainy season. Mean annual temperatures are not more than 25°C. The dominant trade winds are the south-west, tropical maritime moisture-bearing wind which leads to heavy precipitation. In spite of this, the region is richly endowed by nature with a lot of tropical rain forest and fertile soils rich for agriculture and abundant water bodies across the entire state. The terrain is generally low lying, about 300m above sea level.

Major health service providers in the state include General Hospitals across the 18 local government areas, the University of Calabar Teaching Hospital, Infectious Diseases Hospital, the Psychiatric Hospital and a lot of private clinics across the state owned by individuals and missions. Almost every community owns either a health center or a health post to meet their immediate health needs before getting to a professional medical doctor.

2.2. Soils and Vegetation

The soils of the Cross River State are generally feralistic with sandy soils on older sedimentary rocks. These are very thick, clayey, red, porous, permeable, supporting plantation and tuber crop production in some part and poor nutrients and fragile soils in other parts due to the influence of human activities on the forest. A combination of geological events, climatic and relief factors has produced diverse and heterogeneous habitat which support a variety of vegetation types (consequently fauna and flora associations) ranging from cold sub-montane forest and grassland to lowland rainforest, freshwater swamp forest and savannah with gallery forest. Several classification of vegetation type has been done in Cross River State, [21] and Cross River State forestry commission, 2010 in [22].

The Cross River state is characterized by complex strata of vegetation ranging from the tropical high forest, through lowland forest to montane vegetation and to guinea savannah in the northern extremities. The state has saltwater swamps, mangrove forests, and dense tropical rain forest. It is observed that out of the remaining 5.5%

tropical rainforest left in the country, Cross River State has a significant portion (4.5%) of the nation's forest resources and supplies a sizable amount of the country's industrial wood for export and domestic markets [23] and Ogunjobi, *et al.* [22]. The tropical high forest exists in three canopies or layers, the top most layers (the crown) about 15-30 meters high is made up of tall trees with shed mostly hard wood, the middle layer that forms the canopy is made of middle ranged trees. The lower layer that is made up of shorter trees, shrubs and ferns, runners and other crawling plant species covers the forest floor.

The population of Cross River state consists largely of the Efik, Ejagham, Bekwarra and Ekoi peoples. Farming is the predominant occupation of the people of Cross River state and the National Park host communities, Palm oil and kernels, timber, cocoa, and rubber are the major cash crops grown in the area. Major food crops include yam, cassava, rice, and corn (maize), cocoyam, banana, plantain, melon, millet, guinea corn among others. Although, Egbai, *et al.* [24] observed that a sharp decline of soil nutrients which has resulted in reduced crop yield in Nigeria is increasingly noticeable throughout the country. Majority of the people are hunters, traders, timber dealers, and palm wine tappers, handful of the population are civil/public servants and students Ogunjobi, *et al.* [22] and Oates [21]. Ethno-botanic surveys revealed that flora and fauna materials play a central role in the day to day living of the various local communities in the state

2.3. Water and Soil Sampling Techniques

Randomize systematic sampling techniques was employed to select sampling points (water sources; wells, streams and boreholes) that are spatially distributed within the study area. Water samples from six (6) boreholes, six (6) streams and six (6) hand dug wells were taken from the six different locations that makes up the study area, and respective geographic positioning system (GPS) was taken for each sampling point and landfill site. While the adjoining soils to the mortuary sites were also taken from 18 spots, that is, six spots per study site. The soils are collected thus; from the mortuary site and one from any slope 100M away from the mortuary facilities. Physio-chemical and microbial analyses of the water and soil samples collected from the study area were done using established laboratory techniques and procedures. The physico-chemical property analysis of the soils collected was analyzed based on some parameters such as the soil pH, electrical conductivity, texture, moisture, temperature, soil organic matter, available nitrogen, phosphorus and potassium.

Structured questionnaire made up of twenty items was also administered to the mortuary attendants and residents of the communities and adjoining communities where these embalmment homes are located. Simple percentage and correlation analysis was done to examine the effect of embalmment chemicals on the environment and health of residents.

2.4. Statistical Analysis

Multivariate statistical analysis was applied for the physico-chemical parameters using correlation matrix so as to evaluate factors influencing the groundwater chemistry and sources of pollution in the aquifer of the areas.

Table-1. Sample distribution by mortuary facilities in Cross River State, Nigeria

S/no	Location	Site	Sample collected
1	Biase	Ultra Modern Morticians	Water and Soils
2	Ikom	Good Home	Water and Soils
3	Bekwarra, Abuochiche	General Hospital Mortuary	Water and Soils
4	Bekwarra, Gakem	Decency Morticians	Water and Soils
5	Yala, Okpoma	Faithful Home Embalmment services	Water and Soils
6	Ogoja, Abakpa Junction	Decent morticians and Hearse services	Water and Soils

Some laboratory procedures were also adopted to test the chemistry of the adjoining soils for the impacts of these embalmment chemicals as used by these morticians. A comparative analysis was further done on the different soils samples, the one directly affected by the immediate mortuary facilities and those away from the facilities.

3. Results and Discussion

Physical and chemical property analyses The results of the water sample analysis collected from the field was juxtaposed against the World Health Organization's (WHO) allowable water quality standard and acid concentration, the result of the sampled surface and ground water physical properties are as presented in Table 2. From the result, it is observed that in all sample locations, appearance, odor and turbidity fall within the WHO recommended limits.

Temperature ranged between 28.9^oC - 29.6^oC below the standard limit set by the WHO, which is between 35^oC - 40^oC, implying that there is the presence of extraneous materials (bodies) which are foreign or alien to the water bodies such as active micro-organisms [25-27].

Table-2. Physical characteristics of the water samples analyzed and comparison with WHO Standard

Sample sites	Turbidity	Odour	Appearance	Temp (°C)	Stream pH	Hand dug well pH	Borehole pH	pH Value \bar{X}
WHO Standard	5 NTU (mg/l)	Odourless	Colourless	35–40	4	8	8	7.34
Biase	Clear	Odourless	Colourless	29.6	4	8	7	7
Ikom	Clear	Odourless	Colourless	28.8	5	6	7	6.34
Abuochiche	Clear	Odourless	Colourless	28.9	6	7	8	7
Gakem	Clear	Mild	Colourless	28.9	5	7	8	6.77
Yala, Okpoma	Clear	Odourless	Colourless	30.1	6	8	7.1	7.44
Ogoja, Abakpa Junction	Clear	Odourless	Colourless	29.3	8	6	7	7

Though if the cases are considered individually, the mean pH value of respective sample points indicates that the sample for Ikom 6.34 and Gakem, 6.77 are acidic. There might be other reasons for this increased acidic charge for these water samples, but the immediate conclusion is that the formaldehyde used for embalmment has played a role in the increase in the acidic content of the water samples. All other sample points fell within the allowable WHO standard for water quality, 7-7.44. During the analyses of the water samples from different points, it was observed that there were some extraneous materials found in the samples analyzed among which is the presence of the growth of algal bodies within and around the streams and hand dug wells. This could be a suggestion that the chemicals used for embalmment may have recharged the water nutrient content, attempting to increase the nutrient content of the water body, hence paving way for algal bloom and subsequently leading to eutrophication. It is worthy to mention that the results of analysis show similar results for both water and soil samples.

There was some compliance with the chemical properties of the water sample based on the WHO water quality standard, but the presence of trace elements in the sample analyzed became worrisome. While those of Zinc (Zn), Sulphates (S) and Nitrates (N) were 100% in compliance with the WHO standards, other components found in the water sample include formaldehyde, glutaraldehyde and methanol, which are the principal composition of the embalmment fluid. Principally, these chemicals are very poisonous and their presence was found in the water samples analyzed. These chemical properties content can be seen on [table 3](#).

Table-3. Comparison of sample water chemical properties with the WHO/NSDWQ standard

Sample	pH	Cidex/ Glutaral mg/L	CH ₃ OH/ MeOH mg/L	Pb (mg/L)	SO ₄ (mg/L)	NO ₃ (mg/L)	Cd (mg/L)	Zn (mg/L)
WHO Standard	6.5-8.5	250	200	0.015	250	10	0.003	1.5
NSDWQ	6.5-8.5	2.433	2.34	0.01	100	50	0.003	3.0
Biase	7.90	2.45	3.33	0.043	266	0.701	0.3	0.083
Ikom	6.25	1.35	2.232	0.086	251	1.401	0.1	0.111
Abuochiche	6.21	3.123	2.78	0.043	255	0.601	0.1	0.028
Gakem	6.59	2.233	2.44	0.243	229	0.701	0.3	0.056
Yala, Okpoma	6.42	1.99	2.344	0.130	268	1.401	0.1	0.056
Ogoja, Abakpa Junction	7.99	2.32	3.22	0.086	258	1.501	0.2	0.083

Nigerian Standards for Drinking Water Quality (NSDWQ) maximum allowable water quality WHO values are the maximum permitted levels in the WHO Drinking Water Quality Guideline.

3.1. Hydrogen Ion Concentration (water pH).

From the result of the chemical properties of the water samples analyzed in [table 3](#), it is observed that the water samples have pH of all the groundwater samples recorded acidic conditions as the borehole and hand-dug well water samples ranged from 6.21-6.42, and 7.90 to 7.99 respectively ([table 3](#)). From the result of this analysis, it is found that the hydrogen ion concentration (pH values) is quite different from those reported in earlier studies [8, 9, 16]. The value shows the presence of acidic content in most underground water sample points (boreholes and hand dug wells) than those reported earlier by [Kim, et al. \[7\]](#); [Williams, et al. \[10\]](#); [Canninga and Szmigina \[3\]](#) and [Hammer, et al. \[28\]](#) and [Wen-Xiong and Qiao-Guo \[27\]](#).

In their respective submissions, these authors found that in the assessment of groundwater quality, in the industrial area of Sharada, Kano, the acidic content was beyond the standard set by WHO and NSDWQ. It is possible that the acidic content of the water sample analyzed and the result from this analysis could be attributed to the metal content in the cidex, glutaral and the methanol found in the formaldehyde used as embalmment fluid within the local mortuaries in the study area. It could also be as a result of the presence of heavy metals contaminants present in the leachate emanating from the waste and other waste water buried from the embalmment sites. However, in this study, it has been found that the result of the analysis, water samples from Ikom, Abuochiche, Yala and Gakem mortuary sites, the chemical property level exceeded those recommended by [World Health Organization/ National Standard for drinking water quality \(WHO\) \[29\]](#) and currently those of USEPA, (2013).

3.2. Lead (Pb)

The result of the analysis also showed that lead (Pb) concentration was also higher than the recommended WHO/NSDWQ level in all groundwater samples analyzed. Same result was obtained for the soil samples analyzed. Lead presence in the entire water and soil samples from the different mortuary sites indicated concentration range 0.043 -0.234 mg/L, which is far higher than those of WHO of 0.015 mg/L and that of NSDWQ of 0.01 mg/L respectively. There is the likelihood that the presence of lead (Pb) in the under groundwater samples could be traced to the disposal of lead rich materials from other cleansing agents used in the mortuaries that could have undergone decomposition and subsequently percolated or leached into the underground water thereby polluting the groundwater. By implication, the high concentration of lead (Pb) in the groundwater shows higher level of lead pollution in the water samples. This is in agreement with the findings of [Katz and Salem \[1\]](#); [Chou, *et al.* \[11\]](#) and [Huang, *et al.* \[2\]](#) whose results shows a higher concentration of lead (Pb) content in high concentration in mortuary sites. This is an indication of pollution of ground water and adjoining soils by the presence of high concentration of lead. Though, this result is in disagreement with the finding of [Keijzer and Kok \[5\]](#) who found that lead is not a constituent part of ground water pollution, since its presence is only in minute quantity, hence cannot make any significant contribution to ground water pollution. The high concentration of lead found in this study is also a confirmation of the finding of who found that in their study, the minimum concentration of lead was found to be 0.012 and the maximum concentration levels of lead (Pb) was 0.153mg/L respectively. It is in the light of this submission that [Prasad, *et al.* \[30\]](#) posited that if people are excessively exposed to Pb in large concentration, it could result in the development of various neuro-developmental challenges; the authors further warned that this could lead to 4.1-fold increased risk of attention-deficit hyperactivity disorder in children. It is however concluded that the concentration of lead (Pb) found in these water samples were sufficient enough to cause serious health challenges to the people residing within the study sites.

3.3. Nitrates

Looking at the concentration of Nitrates in the water and soil samples analyzed, it was found that there was a high concentration of Nitrates in the ground water and in the adjoining soils from hand dug wells, boreholes and streams. The results of the analysis show that the concentration of Nitrates in the groundwater was within the standards and guidelines set by [World Health Organization/ National Standard for drinking water quality \(WHO\) \[29\]](#); NSDWQ, (2007) and USEPA, (2013) for water quality.

Results in [table 3](#) shows that the Nitrate concentration ranges from 0.701 to 100 mg/L. Studies have however shown that high nitrate concentration could interfere with the functioning of the red blood cells during the transportation of oxygen within the red blood, thereby causing blue baby syndrome. Blue baby syndrome is a medical condition that is usually detected in infants between 12-60 months of birth, [\[9, 16\]](#). Nitrates were higher in Ikom, Biase, Abuochiche and Gakem studied sites, and was lesser at Okpoma, Yala. This could be alluded to the fact that Nitrate is part of the chemicals generated from the release of waste materials including waste water from the mortuary sites. It could also be said that Nitrates are also a constituent part of the chemicals used for the embalmment of corpse.

3.4. Cadmium (Cd)

Result of the analysis in [table 3](#) shows that Cadmium, (Cd) concentration range from 0.003 to 0.2 mg/L. From this analysis, it was also observed that Cadmium concentration was far higher than the [World Health Organization/ National Standard for drinking water quality \(WHO\) \[29\]](#), NSDWQ (2007) and USEPA, (2013) standards and guidelines for allowable water quality limit in all the samples collected from the different sites for analysis (see [table 3](#)). Efforts to explain this high level of cadmium concentration points to one thing, the embalmment fluid deposited, the waste generated from the embalmment activities and buried on the ground increased the cadmium concentration. This could be from the plastic containers used in the storage of the chemicals, the polythene used and also from the paint used in the building that houses the mortuary facilities in all the sites where samples were collected for the study. This finding is a confirmation of the earlier finding of [Dent and Kent \[8\]](#); [Kim, *et al.* \[7\]](#) and [Gonçalves, *et al.* \[31\]](#) whose result shows that in most mortuaries and cemeteries, the water and soils within the adjoining areas are usually high in Cadmium concentration. This is so because most of the items including the containers used for these chemicals have high amount of Cadmium used in the production of such containers. Plastics and polythenes are rich in Cadmium, hence the concentration in these water and soil samples from the study sites. This is therefore the source of the Cadmium pollutant in the ground water and soil samples.

3.5. Zinc (Zn)

The analysis in [table 3](#) shows that the amount of Zinc found in the water samples analyzed is within the acceptable limits set by WHO, NSDWQ and USEPA. This is so because if a comparison between the WHO/NSDWQ/USEPA standard and guidelines and the result of the analysis, one will observe that that of the study is far less than the standard set by these international organizations. The result shows that Zinc concentration is between 0.028-0.111 mg/L, while that of WHO is 1.5 mg/L and that of NSDWQ is 3.0 mg/L, therefore the concentration of Zn in the study area is minimal as compared to those of WHO and NSDWQ. This result has come to confirm the earlier finding of [Williams, *et al.* \[10\]](#), [Canninga and Szmigina \[3\]](#) and [Ahmed \[32\]](#) whose studies found that Zn concentration in underground water is minimal in waste dump site, while same is obtainable in cemeteries and mortuaries respectively.

3.6. Sulphate (SO₄)

The result on [table 3](#) shows that Sulphate concentrations in the study area range from 251 to 268 mg/L, as against WHO 250 mg/L and NSDWQ's 150 mg/L. It therefore shows that the Sulphate concentration in the sampled soil and water were higher than the international standards and guidelines for soil and water quality. This shows that there is a high concentration of Sulphate in the underground water from the sampled sites. Further analysis shows that there is a high concentration of Sulphate in ground water, in hand dug well; the sulphate content is 0.56-3.44 mg/L, in stream water, 0.22-0.98 mg/L, while in boreholes, the concentration of sulphate is 0.344-2.98 mg/L. It is however observed that in Ikom, the concentration is 3.55 mg/L, which is also high. [Chou, et al. \[11\]](#) and [Huang, et al. \[2\]](#) found low Sulphate concentration in ground water analyzed from mortuary and cemetery sites., whereas, studies like those of reportedly found even higher concentration of SO₄ as compared to this present study and those of [Chou, et al. \[11\]](#) and [Huang, et al. \[2\]](#) respectively.

3.7. Cidex/ Glutaraldehyde

These are disinfectants, others include methanol, ethanol, phenol, humectants and water. The results obtained on the concentration and determination of metals in the groundwater and soil samples assessed in this current study is synonymous with the report of the study conducted by Oyeku and Eludoyin (2010) in [Anichkov, et al. \[33\]](#), on the possibility of soil and groundwater pollution due to the influence of the landfill dumpsite in Ojota, Lagos state. These authors reported higher concentrations of Fe, Pb and Cd in their study compared to the levels detected in this current study.

Remarkably, the current situation in the study area has been reported by [Anichkov, et al. \[34\]](#) as a result of the siting of groundwater sources in areas where indiscriminate mortuaries and waste disposal is rampant which would inevitably lead to soil and groundwater contamination.

Table-4. Descriptive Statistics of Metal Concentrations in Groundwater Samples

Parameters	Range	Mean	Standard Deviation
pH	0.83	8.06	0.29651
Cd	0.2	0.1833	0.09832
Pb	0.087	0.0718	0.03544
Zn	0.083	0.0695	0.02889
SO ₄	1.15	0.2403	0.45534
NO ₃	0.7	1.051	0.383406

3.8. Bacteriological Analysis

The bacteriological characteristics of the samples tested are as reported in [Table 5](#). It can be seen in [Table 5](#) that the highest average total count of bacteria detected in all the water samples that were bacteriologically assessed occurs in W3 ($12.2.4 \times 10^1$ CFU/ml), while the lowest average total count recorded can be seen in B3 (9.6×10^1 CFU/ml). It can be said that these ground water sources are not potable enough for human consumption as the presence of bacterial counts have negated the zero bacterial count recommended by WHO. However, these results when subjected to statistical analysis revealed that the bacterial counts are not significant ($P > 0.5$).

The variance is higher than WHO recommended limit which further confirms bacteriological pollution, not limited to human sources and coming perhaps from the activities of the local embalment's and remains of chemicals and disinfectants or even from grave yard. Used waste water, formaldehyde and disinfectants are discharged into the environment, some buried, others just poured away could contribute to bacteriological pollution; affecting water, soils, other environmental organisms and human health. The results obtained in this study are in concordance with the report submitted by Akinbile (2006); Omofonmwan and Esigbe (2009) cited in [Brenner \[14\]](#) which concluded that the disposal of fecal materials to the public disposal systems (landfill) end up polluting groundwater sources. Lack of functional sewage systems in most sites where these local mortuaries are located contributes to exacerbate the situation.

These results showed that all the six (6) samples do not satisfy the WHO requirements stipulated for the portability of water fit for human consumption and soils for agricultural productivities. The results obtained in this current study are in accordance with the submissions of [Udoaka, et al. \[35\]](#) and [Vohra \[36\]](#) regarding groundwater pollution due to leachate emanating from the embalment sites (mortuary location). The WHO and NSDWQ standards of 1 and 10 in 100 CFU/ml for other coliforms respectively, have been surpassed by all the water samples analyzed as they all recorded over 1/100 CFU/ml ([Table 4](#)).

Table-5. Total bacterial counts in sampled streams, bore-hole and hand-dug well water

Sample	Dilution Factor	Total Count (CFU/ml)	Average Total Count (CFU/ml)
B1	10 ⁻¹	173 x 10 ⁻¹	10.9 x 10 ²
	10 ⁻²	140 x 10 ⁻²	
	10 ⁻³	88 x 10 ⁻³	
	10 ⁻⁴	36 x 10 ⁻⁴	
B2	10 ⁻¹	178 x 10 ⁻¹	11.0 x 10 ¹
	10 ⁻²	144 x 10 ⁻²	
	10 ⁻³	78 x 10 ⁻³	
	10 ⁻⁴	40 x 10 ⁻⁴	
B3	10 ⁻¹	166 x 10 ⁻¹	9.6 x 10 ¹
	10 ⁻²	128 x 10 ⁻²	
	10 ⁻³	62 x 10 ⁻³	
	10 ⁻⁴	30 x 10 ⁻⁴	
W1	10 ⁻¹	184 x 10 ⁻¹	12.0 x 10 ¹
	10 ⁻²	152 x 10 ⁻²	
	10 ⁻³	100 x 10 ⁻³	
	10 ⁻⁴	44 x 10 ⁻⁴	
W2	10 ⁻¹	188 x 10 ⁻¹	11.4 x 10 ¹
	10 ⁻²	156 x 10 ⁻²	
	10 ⁻³	74 x 10 ⁻³	
	10 ⁻⁴	38 x 10 ⁻⁴	
W3	10 ⁻¹	190 x 10 ⁻¹	12.2 x 10 ¹
	10 ⁻²	154 x 10 ⁻²	
	10 ⁻³	100 x 10 ⁻³	
	10 ⁻⁴	44 x 10 ⁻⁴	

In the analysis of the combination of chemical used for the embalment of corpse and their effects on the health of humans, it was established that the most prominent chemicals used in the formulation of the embalment fluid include Glyoxal (oxaldehyde), Glutaraldehyde, formaldehyde, Sodium nitrate, tetrafluoroborate and Phenoxyethanol, Methyl-3-octyloxymethylimidazolium, Phosphonium chloride (Tetrakis or hydroxymethyl) and Boric acid.

3.9. Formaldehyde

The result of analysis shows that formaldehyde is one of the most lethal and strongest fungicidal, insecticidal and bactericidal chemical. It is established that prolong usage of this chemical as a currying and preservative agent is premised on the purpose that it is an excellent chemical with its antiseptic properties, preventing the decomposition of organisms. This chemical tans the tissues by preventing the destruction of all delicate tissues or structures. Despite formaldehyde fixation of tissues, its use is widely accompanied with some rigid structure. Formaldehyde has a high level lethal effects between about 8 % of 70% alcohol, this intermediate to high level formaldehyde in water (4-8% formaldehyde in water). This position was earlier posited by Mayer [37] and Eneji, *et al.* [6]. These authors observed that formaldehyde has a broad spectrum of action on micro-organisms, this destroys the organism's putrefactory capacity when carried by proper agents, thereby permitting its penetration of the organisms. Formaldehyde can also react with protein forming a new variant of chemical compounds called resin which are stable and not fit for food for all organism both the environment and human health.

This chemical is also known for its hardening properties; formaldehyde has various negative effects when used for embalment. It is used because it hurriedly coagulates blood, converting the tissues to a grey hue once it mixes with the human blood, immediately decolorizing, milking out the fluid in the tissues, convulses the arteries and capillaries. While in living organism, it does same and also effects deteriorating with age with an unpleasant smell. Formaldehyde is a chemical that is highly reactive to aldehyde gas, it is formed through the process of oxidation or incomplete combustion of hydrocarbons, forming the formaldehyde gas from the combustion of organic matter. This chemical can also be produced through a secondary process in the air from photochemical reactions involving nearly all classes of hydrocarbons pollutant especially during the current trend of climate change (National Toxicological Program, 2010).

3.10. Sodium Nitrate

This is a preservative, it is also known as curing salt, it inhibits the growth of bacteria and fungi, especially clostridium botulinum preventing botulism by helping to preserve the incurred body

3.11. Glutaraldehyde

This finding has come to agree with that of Bedino [38] that glutaraldehyde is also a very reactive dialdehyde, used for various synthesis of chemicals in a more complex laboratory procedure. This study has established that glutaraldehyde exhibited more superior and lethal chemical composition with protein fixing than formaldehyde in numerous perspective. Though, it was used as a sterilizer and disinfectant [38]. It was discovered that glutaraldehyde

reacts principally with proteins forming aldol polymers forming in reaction with proteins the aldol polymers of glutaraldehyde react to form α , β -unsaturated amino type reaction products that are highly resonance-stabilized and very resistant to acid hydrolysis and rehydration [38]. Glutaraldehyde appears to react chiefly with the amino groups of lysine, but also tyrosine, tryptophan and phenylalanine. This result had come to further confirm the earlier work of De Groot, *et al.* [39]. This chemical act as irritant to the bronchial and laryngeal mucous membrane and prolong exposure produces localize oedema with eye irritation and contributing to forming glycoma and weaken the allergic capacity of the human system and the eyes.

3.12. Boric Acid

This was used for anatomical preservation; it forms borate complex with the carbohydrates residues of glycoproteins in some functional alkaline phosphates. Because of the effects of this chemical, authors like [40] assumed that the boric acid content in Thiel's embalming fluid is responsible for a distinct major modification of the integrity and the alignment of muscle fibers. The muscle fibers had a cut-up 'minced' appearance, but remained aligned; the conjunctive collagen fibrils were undisturbed. This discovery enforced the argument that the acids are well known to have very corrosive effects on proteins and, in this special case, muscle proteins. The only acid present in Thiel's mixture is boric acid, thus they suspected it to be the reason for the observed damage, as the other chemicals of the Thiel's embalming solution could not be involved in this very singular destruction of the muscles. This finding led to the conclusion that the human borate exposures, even in the highest exposed cohorts, are too low to reach the blood (and target tissue) concentrations that would be required to exert adverse effects on reproductive functions [6, 36].

3.13. Glyoxal

Glyoxal is a chemical component of the embalment fluid produce to kill organisms that produces slime, because it contains chromophores, which tend to stain tissues yellow. It is a very minimal component of the embalment fluid; therefore, its composition is very minimal in all the system. Despite its small percentage, it attacks the amino acid of the protein, lipids and nucleotides with its very reactive carbonyl groups. This creates a sequence of non-enzymatic reactions called glycation, which yields a stable advanced glycation, altering the protein function. This process makes the enzymes inactive and disturbs the cellular metabolism, this in turn impairs proteolysis and the inhibition of cell production and synthesis of protein in plants and animal including man.

3.14. Phosphonium Chloride

This is a chemical combination and a reaction from the synthesis of phosphine, hydrochloric acid and formaldehyde, which is usually absorbed through the human skin. It is usually used as flame retardant in cotton fabrics. Some scholars also call this chemical tetrakis or hydroxymethyl. It can also be absorbed orally, once absorbed, it affects human liver because it also contains highly lethal carcinogenic compounds

3.15. 1-methyl-3 Octoyloxymethylimidazolium Tetraflouroborate

This is an ionic liquid used as substitute for formaldehyde, there are a class of organic salt which at room temperature are liquid in their purest form. They are principally composed of organic cation and heterocyclic aromatic and non-aromatic compounds. They hardly bond with amino acids of protein compounds, but can form ionic pairs with deoxyribonucleic acids (DNA) and Ribonucleic acids (RNA), they restrict access of water into tissues. These ionic liquid kills bacteria and fungi inhibiting biological decay or decomposition of tissues. Unger, *et al.* [41], found that ionic liquids are considered environmentally sustainable because of its versatility and their green credential, but not all ionic liquids are environmentally benign or friendly.

4. Conclusion

The results obtained from the laboratory analyses of selected groundwater and soil samples around the mortuary sites studied indicated that formaldehyde, glutaraldehyde, humerants, metals, coli forms, microorganisms and other contaminants from the mortuary sites have impaired the soil and water quality. The concentrations of Fe, Cd, Zn, SO₄ and NO₃ and bacteriological contamination coupled with other soil and water quality parameters in some of the sampling locations highly exceeded the WHO and NSDWQ acceptable limits. The use of formaldehyde and other embalment solutions are deleterious to human health. However, sodium borate, glyoxal, sodium nitrate, phosphonium chloride and 1-methyl-3 octoyloxymethylimidazolium tetraflouroborate has less environmental effects including human health. The most common health problems in people exposed to formaldehyde include irritation of the eyes, nose, and throat. However, formaldehyde have been found to cause serious environmental and occupational asthma, among the workers and the people around where people are exposed to serious formaldehyde usage. Serious exposure to formaldehyde and other embalment's solution has been found to result in irritation and damage to the lining of the mucosal lining of the nose and throat. Above all, the exposure of the environment to local embalment, coupled with these chemicals has affected the soils and water quality of the environment, while increasing the amount of greenhouse gases in the atmosphere of the immediate environment, reducing soil and water quality and affecting human health.

5. Recommendations for Policy Directions

Based on the finding from the research, it was recommended among others that:

1. Green embalment procedures should be encouraged, while embalment services should be located far away from residential areas and water bodies.
2. Wastes from embalment/mortuary services should be sustainably disposed to avoid these chemicals from contaminating the environment and affect human health.
3. Embalment or morticians should be encouraged to locate their embalment services within a health facility, where the waste from these embalment chemicals and fluid can be properly managed.
4. The recommendation from the WHO and the National Standard for Drinking Water Quality (NSDWQ, 2007) should be strictly followed, where embalment houses are to be located away from streams, water bodies and residential or public places,
5. Fine should be imposed on morticians who keep cadavers at home and in residential areas within the communities. This will serve as a deterrent to those who still keep corpse at home for embalment's.
6. It was also recommended that the practice of burying corpse at home be discouraged, especially where boreholes, streams and hand dug wells are already in existence.

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