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The Effects of Cement Dust on Albino Rats (*Rattus norvegicus*) Around West African Portland Cement Factory in Sagamu, Ogun State, Nigeria

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Abstract: A total of 10 Albino rats obtained from an animal house in Lagos were exposed to cement dust for six weeks at the West African Portland Cement Factory at Sagamu, Ogun State. Two others were kept in an environment free from cement dust but within the same climatic zone. The weights of rats exposed to cement dust in 2nd, 4th and 6th week were significantly lower than the ones kept in the cement free zone ($p<0.05$). The difference in weight increased with the period of exposure to cement dust. The chemical analysis of the lung tissues of the rats exposed showed high levels of Calcium, Silicon, Zinc, Aluminium and Iron compared to the unexposed rats. The histopathological examination of internal organs of exposed rats showed loss of mycocardial striations, interstitial oedema, hyalinization, progressive necrosis and atrophy of the cells of the heart. The liver had cellular oedema, haemorrhage of the tissue and partial necrosis. The kidney showed cortical necrosis and tubular atrophy while the lungs showed interstitial oedema and cellular atrophy. The results further confirm that cement dust is pathogenic and toxic. There is no doubt that people who work in the cement factory stand the risk of being affected with different types of diseases arising from exposure to cement dust. This calls for the use of modern machines to reduce the amount of cement dust that gets to the environment. Moreover, the regulatory agencies should be more serious in monitoring industrial activities to reduce the incidence of all forms of environmental pollution including air pollution arising from cement dust.

Key words: Cement dust, air pollution, albino rats, *Rattus norvegicus*

INTRODUCTION

Naturally, there are global balances in the different compartments of the earth ecosystem. However, man and other anthropogenic activities have brought imbalances to the earth ecosystem. The different activities of man which produce harmful effects to environment are known as pollution and such activities are mainly agricultural and industrial practices (Lori, 1996). Cement dust from manufacturing and processing of cement is a serious atmospheric pollutant. There is no doubt that a large amount of waste substances, effluents, chemicals and energy are introduced into the environment through several sources (Paivoke, 2002). Air pollution has become a major threat to the survival of plants and animals in industrial areas (Gupta and Mishra, 1994) and air pollution from industries and addition of toxic substances to the environment are also responsible for altering the ecosystem (Nigragau and Davidson, 1986). Furthermore, Laws (2000) stated that pollutants are introduced naturally into the environment through weathering of soils and rocks, volcanic eruptions, floods, wild forest fires, sea saltsprays and wind; as well as anthropogenic means such as from smelters, solid waste, incineration, coal and oil combustion, cement production and phosphate fertilizers.

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Even in the 21st century, millions of people are working daily in a dusty environment. They are exposed to different types of health hazards such as fumes, gases and dust, which are risk factors in developing occupational disease. Cement industry is involved in the development of structure of this advanced and modern world but generates dust during its production. Cement dust causes lung function impairment, chronic obstructive lung disease, restrictive lung disease, pneumoconiosis and carcinoma of the lungs, stomach and colon (Meo, 2004). Other studies have shown that cement dust may enter into the systemic circulation and thereby reach the essentially all the organs of body and affects the different tissues including heart, liver, spleen, bone, muscles and hairs and ultimately affecting their micro-structure and physiological performance. Lung and laryngeal cancer can be caused by cement dust (Stern *et al*., 2001). Most of the studies have been previously attempted to evaluate the effects of cement dust exposure on the basis of spirometry or radiology, or both. However, collective effort describing the general effects of cement dust on different organs and systems in humans or animals, or both has not been published. Therefore, one of the aims of this study is to add to information on the potential toxic effects of cement dust on mammals such as albino rats. The results obtained will further sensitize the cement mill workers and the regulatory agencies in Nigeria by providing them with information regarding the health risks and hazards of cement dust. This type of information is of utmost importance not to the regulatory agencies but also to the cement factory management.

Cement is a fine, grey or white powder which is largely made up of Cement Kiln Dust (CKD) and a by-product of the final cement product, usually stored as waste in open-pits and unlined landfills (Hansen, 1998a, b). Pollutants such as particulate matters, sulphur dioxide, nitrogen dioxide, volatile compounds, long lived dioxins and heavy metals all arise from the manufacturing and burning process of cement. Moreover, studies have shown that one ton of carbon dioxide gas is released into the atmosphere for every ton of Portland cement which is made anywhere in the world leading to global warming (Joseph, 1994). Pollutants from cement dust have been known to be toxic, mutagenic or carcinogenic to animals and are thought to play a part in a variety of maladies, including cancer, lupus, immune disease, allergies and asthma. The development and severity of the injury caused by the cement dust on plants or animals depend not only on the concentration of the pollutant, but also on a number of factors. These factors include the length of exposure to the pollutant, the species and its stage of development as well as the environmental factors conducive to building of the cement dust to the preconditioning of the organism, which make it susceptible or resistant to injury (Heather, 2003). A single short-term exposure to cement dust is not likely to cause serious harm. However, exposure of sufficient duration to cement dust can cause serious, irreversible tissue destruction in form of chemical burns, including third degree burns. It has been found that there was significant increase in ill-health among children in schools near cement kiln compared to those out of the area (Joseph, 1994). Acute effects such as eye, nose, upper respiratory tract irritation, cough, expectoration, shortness of breath and wheezing have been recorded in humans due to exposure to cement dust (Lanaqui *et al*., 2001). Haematological and histopathological parameters are also another good measure in diagnosing the functional status of an animal exposed to toxicant. Decrease in red blood count of workers exposed to cement dust in India has been reported (Calistus *et al*., 2002). Histopathological changes in the testis of the spague Dawley rats following orally administered manganese has been recorded. The study revealed the degeneration of the germinal epithelium with seminiferous spermatozoa, spermatids and seminiferous tubules. Cement is an important ingredient of concrete and mortal. There is no way its use can be avoided in building construction hence production of cement remains an important industry. It is made of several materials which is a mixture of fine dust in the dry process or in the form of slurry in the wet process of calcium, silicon, aluminium, ferric and magnesium oxides. Other trace constituents include potassium and sodium sulphate compounds, chromium compounds and nickel compounds.

Most of the constituents of cement have been found to be toxic to organisms in the environment (Fatma *et al*., 2001; Schemback, 1998). Sagamu and its environs have been exposed to cement dust for a long time. There is no information on the effect of cement dust from this factory on living organisms particularly on animal species inhabiting the area. Such information should be invaluable as it will help us to know more about the danger the cement dust as an atmospheric pollutant poses to animal species that inhabit the area close to the factory and humans who work in the industry. Furthermore, this investigation is relevant and of interest going by the way pollutants are indiscriminately discharged into our environment in Nigeria with little or no database for use by the regulatory agencies in their monitoring programmes. The results from this study will therefore assist the regulatory agencies to advise the management of the cement factory on the use of modern machines that can reduce the amount of cement dust that get to the environment. This type of control strategy is being used in countries like United States of America to ensure that less cement dust is released to the environment (Ballal *et al*., 2004).

MATERIALS AND METHODS

Description of Study Site

Sagamu cement factory is the largest cement factory in West Africa. The cement factory is located along Lagos-Ibadan motorway. It is on the right hand side from Lagos and about 2 km away from Sagamu. Sagamu is a nodal city in Ogun State in South Western, Nigeria on latitude 6°5′ N and longitude 3°6′ E and its inhabitants are predominantly farmers and traders (Ajiboye, 2005).

Experimental Design

Source of Test Organism

A total of 12 white rats commonly known as albino rats of the same age (about 30 days old) were purchased from an animal farm house in Lagos in March, 2006. Their weights were determined and recorded.

Experimental Plan

Ten of the rats were used for test experiment while the remaining 2 were used for control experiment. The rats were put in cages with maximum of two rats (a male and a female) in a cage to avoid overcrowding and cannibalism. The cages of the test experiment were located 50 meters away from the cement factory at Sagamu. The control experiment was placed 5 km away from the cement factory in a cement dust free environment but within the same climatic zone. The experiment commenced in mid March, 2006, a week after the purchase of the rats. The rats in test and control experiments were weighed second, fourth and sixth week and their weights were recorded. Their internal organs (heart, liver, lungs, kidneys and reproductive systems) were removed for chemical analysis and histopathology examination.

Chemical Analysis of Internal Organs

The chemical analysis was done by Atomic Absorption Spectrophotometer using the UNICAM model 969 spectrophotometer at the Environmental Laboratory.

Preparation of Internal Organs for Histopathology Examinations

The internal organs were prepared for histopathology examinations using the methods of Taylor *et al*. (2003).

Fixation

The tissues were killed rapidly using a fixation known as bound's fluid. This is very important so that the original shapes and structures of the tissues are maintained and hardened so that it will be easy to make thin sections.

Dehydration

The tissues were dehydrated gradually and carried out by series of increasingly concentrated ethanol/water mixtures and finished in pure ethanol. The aim of dehydration was to remove water in the tissues and prepare the tissue for infiltration with an embedding medium, which will not mix with water.

Clearing and Embedding

Because alcohol does not mix with some of the common embedding media (e.g., wax), it was replaced with xylol, a clearing agent that does not mix with embedding media. The tissues were embedded in molten wax and allowed to set. The wax (embedded medium) allowed very thin sections of the tissue to be cut.

Sectioning and Staining

The embedded tissues were sectioned using a microtome. A few micrometers thick were cut from wax-embedded tissues using knife. The tissues were then stained using mercury oxide at low concentration. Staining allowed contrast to be obtained between different structures because ordinarily most biological structures are transparent. Before staining the wax-embedded sections, the wax was dissolved away and the tissues partially dehydrated.

Mounting

The final stained sections were mounted on glass slides in glycerine, a resinous medium that excludes air and protect them indefinitely.

RESULTS AND DISCUSSION

The results of this study show that cement dust can affect animals because the weights of the rats exposed to cement dust were lower than the unexposed rats (Table 1, 2). The mean weights of the rats exposed to cement dust were significantly lower than the weights of the unexposed rats ($p<0.05$) as shown in Table 3. The rats exposed to cement dust gained less weight than the unexposed rats (Table 4). Levels of chemicals in the lungs of the rats before and after exposure to cement dust. It is evident that the levels of calcium, silicon, zinc, aluminium and iron which are major constituents of cement dust that were detected in the lungs after exposure were higher than the levels before exposure (Table 5). For instance calcium as calcium carbonate was 0.01 g on the start day and it increased to 0.02, 2.42 and 6.01 g by 2nd, 4th and 6th week of exposure, respectively. This shows that in 6 weeks of exposure to cement dust, it has accumulated in the lungs about six hundred times. The histopathology examinations of the tissues of exposed rats further confirm that indeed cement dust can be toxic to animals. The heart showed cell swelling, interstitial oedema and loss of cellular outline, hyalinization of tissue and atrophy of cells in the 2nd, 4th and 6th weeks, respectively. The kidney had cortical necrosis and tubular atrophy in the 2nd and 4th week and severe necrosis in the 6th week of exposure. The liver suffered cellular oedema in the 2nd week, partial necrosis in the 4th week and partial hepatic necrosis in the 6th week. The lung of the exposed rats showed interstitial oedema in the 2nd week, tissue oedema in the 4th week and severe necrosis and cellular atrophy in the 6th week.

Table 1: Weight of rats exposed to cement dust at the start to the end of experiment

		Weight of rats (g)			
Rat	Sex	0 day	2nd week	4th week	6th week
A	F	88.5	131.0	143.1	167.1
B	F	89.0	132.0	142.5	169.1
C	F	88.0	131.2	142.9	167.4
D	F	87.9	131.7	143.2	168.3
E	F	89.1	133.1	143.3	167.9
F	M	108.9	174.5	198.9	201.5
G	M	108.7	169.0	198.3	202.4
H	M	107.5	173.0	196.9	203.2
I	M	108.8	173.9	197.9	202.8
J	M	108.3	172.3	198.8	201.9

Table 2: Weight of rats at cement dust free location at the start to the end of experiment

		Weight of rats (g)			
Rat	Sex	0 day	2nd week	4th week	6th week
K	F	88.3	145.5	180.3	202.5
L	M	107.9	199.0	217.0	227.6

Table 3: Mean weights of rats exposed to cement dust and rats at cement dust free location

Period of exposure	Exposed	Unexposed
0 day	98.6±10.0	98.1±9.8
2nd week	152.2±20.4	172.3±26.8
4th week	170.6±27.6	198.7±18.35
6th week	185.2±17.2	215.1±12.6

Table 4: Weight gain by rats exposed to cement dust and rats at cement dust free location (g)

	Weight gain (g)	
Period of exposure	Exposed	Unexposed
0-2 weeks	53.6	74.2
2-4 weeks	18.4	26.4
4-6 weeks	14.6	16.4

Table 5: Levels of chemicals detected in the lungs of rats exposed to cement dust

	Concentration of chemicals in rats (g)			
Chemicals	0 day	2nd week	4th week	6th week
Ca (as $CaCO_3$)	0.01	0.02	2.42	6.01
Si (as SiO_2)	0.02	0.07	0.12	0.15
Zn (as ZnO)	1.22	1.26	1.34	1.76
Al (as Al_2O_3)	0.02	0.04	0.05	0.08
Fe (as FeO)	0.01	0.02	0.06	0.16

The weight gain by the rats exposed to cement dust was lower than the unexposed rats and this confirms that the constituents of cement dust can negatively affect growth of animals. Pollutants from cement dust have been found to be toxic, mutagenic or carcinogenic to animals (Fatma *et al*., 2001). So the growth rate of the rats exposed to cement dust can therefore be attributed to toxic substances in the cement dust and these include zinc, copper, aluminium, iron and silicon. This finding conforms with the report of Nigragau and Davidson (1986) who found that sulphuric and hydrochloric acids emitted from cement manufacturing plants could impede the growth of animals. Furthermore, Oleru (1984) reported that traces of copper and chromium present in cement dust could play an important role in disturbing the various metabolic processes. Several other symptoms are manifested by organisms that are exposed to cement dust these include dermatitis, tissue rashes, shortness of breath, diminished chest expansion, respiratory illnesses and nail atrophy (Al-Neaimi *et al*., 2001). The fact that the heart,

lungs, liver, kidney and reproductive system of exposed rats showed histopathology changes confirms that the cement dust is pathogenic to rats. The changes became more severe as the period of exposure increased. The kidney suffered severe necrosis, liver showed hepatic necrosis and sand cellular oedema. The lung showed atrophy, severe necrosis and interstitial oedema and the ovary had a lot of fat deposit. The histopathology changes were as a result of cytotoxic agents from the cement dust which caused multi-organ injuries which led to cellular oedema, atrophy and necrosis. Bogue (1991) reported that the exposure to cement dust can cause health effects such as eye irritation, lung allergies, damage to the liver, kidney, gastric system and epidermal irritation. Chronic exposure to cement dust has been reported to lead to several health problems in cement plant workers including marked reduction in total Red Blood Cell count and Haemoglobin (Aydin *et al*., 2004). The abnormal fatty deposition on the ovary and testis might be caused by the inability of the exposed rats to produce offspring. This has been observed by Joseph (1994) in his study where he reported that exposure to cement dust even at lower levels may have effects on the immune system, reproductive processes and foetal development. For instance, Selevan *et al*. (2000) reported that in the periods of elevated air pollution in Teplice, Czech, were significantly associated with decrements in other semen measures including proportionately fewer motile sperm, proportionately fewer sperm with normal morphology or normal head shape and proportionately more sperm with abnormal chromatin. These results suggest that young men may experience alterations in sperm quality after exposure to periods of elevated air pollution, without changes in sperm numbers. Effect of air pollution in the city of Sao Paulo on mouse female fertility has been investigated. It was observed that there was a higher number of live-born pups per animal in the clean chamber than per animal from polluted chamber. These results support the concept that female reproductive health represents a target of air pollutants (Mohallem *et al*., 2005). In other studies apart from fertility related problems, thirty-four patients in the University of Freiburg, Germany, skin clinic who had hyperkeratosis (excess scaling) on feet and hands caused by arsenic poisoning, chromosomal abnormalities were found in lymphocytes. The patients who have been working in the vineyards had been poisoned through exposure to arsenic sprays: others had taken arsenicals as medication for psoriasis (a chronic skin disease of unknown origin) as long as 20 years previously. Some had cancer of the skin (Petres *et al*., 1970). However, this study did not find such effects as cancer, tissue fibrosis, silicosis and pneumoconiosis, all of which have been reported in previous studies. This is probably due to short period of this study. This informs us that there is need for a study that will go on for a longer period than the present study to further confirm the findings of previous studies. Therefore there is still much to be done in this area of research particularly in Nigeria which is a developing country. Results obtained from the research work will form data that can be used to sensitize people who live around the cement industries and other stakeholders that are involved in cement production. This is because the regulatory agencies have no database on this type of study and little data on other types of studies on environmental pollution. Furthermore, the level of mitigation measures, on pollution of the environment by various industries, has not been encouraging. A lot needs to be done in the area of monitoring and enforcement by regulatory agencies and other stakeholders that are concerned about cleaner and healthier environment in Nigeria. The levels of chemicals detected in the lungs of the exposed rats were higher than observed in developed countries like United States of America. This is because there are control strategies in these countries for prevention of dust release by machinery leading to less cement dust in the atmosphere when compared to developing countries (Ballal *et al*., 2004). This is still probably lacking in the operations of the cement factory at Sagamu in Nigeria. Moreover, there was increase in the level of the chemicals in the lungs of the rats as the exposure time increased. The implication of this is that the factory workers are indeed exposed to a great deal of hazard and dangerous effects of cement dust. There is no doubt therefore that the regulatory agencies have to put in place measures to ensure that the amount of

cement dust released from the cement factory is reduced. This can only be achieved by making sure that the equipment that can reduce the amount of cement dust released into the environment is installed by the Sagamu cement factory management and by the management of other existing cement factories and new ones that may be established in the future.

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