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Impact of Long-Term Cement Dust Exposure on Electrolytes and Anion Gap in Enugu Metropolis, Enugu State of Nigeria

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Abstract

Cement dust, a complex mixture of various substances including calcium oxide, iron oxide, chromium, silicon dioxide, aluminum oxide potassium, sodium, sulfur and magnesium oxide can have deleterious effects on human health at long time inhalation. Medical scientists have been interested to know the possible effects of cement dust inhalation on human health, especially at long time inhalation. Ninety (90) adult males were used for this study, 60 construction site workers who have been exposed to cement dust for not less than years, and 30 men who had no history of cement dust exposure. Using Ion Selective Electrode and Calculation Methods, serum electrolytes and anion gabs were estimated respectively. Our results showed that there was significant reduction in serum sodium, chlorides and bicarbonate levels in the cement dust exposed workers when compared with the non-exposed men ($P<0.05$), while serum potassium levels were significantly higher in the exposed group than the unexposed group ($P<0.05$). A significant increase in anion gap ($P<0.05$) was also observed. The above findings are suggestive of imbalances in serum electrolytes and anion gap which may often result to metabolic acidosis and possible respiratory diseases among cement dust exposed individuals in Enugu metropolis of Nigeria.

Keywords: Cement Dust, Electrolytes, Anion Gap, Acid-Base-Balance

Introduction

Cement, a binding agent used in construction has been in use for centuries. The ancient Egyptians, Greeks and Romans used a mixture of lime, water, and volcanic ash to create a binding agent for building structure [1]. In 19th century, Portland cement, the most common type of cement used today, was invented [2]. With the increasing demand for construction and construction materials, cement industries have grown rapidly leading to significant increase in the number of workers exposed to cement dust.

Cement dust, a complex mixture of various substances, including calcium oxide, iron oxide, chromium, silicon dioxide, aluminum oxide, potassium, sodium, sulfur and magnesium oxide can have deleterious effect on human health when inhaled [3]. Most of these components of the cement dust are not friendly to human health. Calcium oxide is a white caustic alkaline crystalline solid at room temperature used in building materials, metal processing, agriculture and sewages treatment. Acute exposure to calcium oxide can cause irritation of the lungs causing cough and /or shortness of breath. Long term exposure can irritate the nose, causing a hole in the bone, brittle nails, thickening of the skin and cracking of the skin [4]. Iron oxide has been linked to increased risk of adverse respiratory outcomes and is biologically benign.

Pulmonary exposure may induce inflammation, pulmonary fibrosis, genotoxicity and extra pulmonary effects [4]. Silicon oxide, a natural chemical mix of silicon and oxygen can produce adverse effects if the fine particles are inhaled for a long time. Its inhalation disposes one to silicosis, a progressive irreversible lung disease, lung cancer and tuberculosis [5].

Aluminums oxide dust is associated with irritation of respiratory tract, coughing, breathing difficulty and lung ailments [6]. While chromium trivalent form I s safe for humans, the hexavalent form found in cement is associated with adverse health effect such as occupational asthma, eye irritation and damage, cancer of lungs and sinus [6]. Magnesium oxide is a white powder and when dispersed in the air it becomes magnesium oxide fume. Magnesium oxide fume can irritate the eyes and nose and when breathed in, it can in addition, cause metal fume fever, a flu-like illness with symptoms of metallic taste in the mouth, headache, fever and chills, aches, chest tightness and cough [4]. Sulfur is an ubiquitous element and natural component of environment and has been known to be of low toxicity and of very little risk to human health. However, sulfur dust can cause some mild eye irritation, dermal toxicity and inhalation hazards. Chronic exposure to elemental sulfur at low level is generally recognized as safe. However, Epidemiological studies show that mine workers exposed to sulfur dust and sulfur oxide, throughout their lives often had eye and respiratory disturbances, chronic bronchitis and chronic sinus effect but no known risk of oncogenic, tetratogenic or reproductive effects associated. [7]. Potassium and sodium components of cement dust are normal components of human blood, regulated by normal physiological functions.

Adverse health effect of cement dust inhalation started to gain attention in the late 19^{th} and early 20^{th} centuries. In 1909, the first case report of "cement lung" was published by Babar Dildar *et al*, 2021 [8]. The term "cement lung" refers to the fibrosis of the lungs and other pulmonary changes caused by inhalation of cement dust [8]. In 2005 several studies investigated the relationship between cement dust exposure and respiration symptoms. For instance, Mwoiselage *et al*, 2005 [9], examined the prevalence of respiratory symptoms among cement worker and found a higher incidence of cough, sputum production and dyspnea, compared to a control group. Similarly, Lataque Hoseni *et al*, 2021 [10], reported that cement workers experienced a higher frequency of respiratory symptoms and pulmonary function abnormalities than non-exposed individuals.

Recent studies have confirmed the health risks associated with cement dust inhalation and further explored the mechanisms of cement dust induced health dangers. For instance, it has been found that cement dust can induce oxidative stress, inflammation and apoptosis in lung cells [11]. These effects have been seen in not mainly the respiratory tracts but also in the skin, eye, and mucus membrane [12], cardiovascular and other systematic disorders [13].

Research on the impact of cement dust inhalation on serum electrolytes is expanding in recent years. Cement dust exposure has been shown to significantly alter some electrolyte balances, such as increasing calcium levels while decreasing phosphorus levels [14]. Serum electrolytes such as sodium, potassium chloride and bicarbonates play critical roles in maintaining some body functions, including fluid balance, muscle contraction and removal of some waste products from the body [15]. Imbalances in electrolytes, particularly sodium and potassium can adversely affect lung function especially in individuals with pre-existing pulmonary conditions such as chronic obstructive pulmonary diseases (COPD) [16]. Imbalances in serum ions such as sodium and potassium, known as cations and chloride and bicarbonate, known as anions can dispose a condition where the body accumulates excess hydrogen ions, known as metabolic acidosis [17, 18]. This may have far reaching effects on various organs, including the Lungs, Heart and kidneys [19, 18]. A measure of the difference between the serum concentration of cations (Positively charged ions) and anions (Negatively charged ions) is termed anion gap [15]. Anion gap is therefore, a calculated value that reflects the balance of cations and anions in the blood. It is typically used to evaluate acid-base disorders. A normal anion gap (3-12 mmol/L) helps to maintain acid-base homeostasis which is partly regulated by the kidneys through the reabsorption and excretion of bicarbonate and hydrogen ions [20]. A stable anion gap, reflecting balance PH, electrolyte and acid-base status is essential for cardiac electrical stability, contractility and normal heart functions [21]. An increased anion gap, often indicting metabolic acidosis, can adversely affects hearts functions, acidosis decreases cardiac contractility and contributes to arrhythmias, as acid-base imbalances can disrupt the functions of ion channels essential for cardiac electro physiology [22].

In other words, impaired kidney function, particularly in chronic kidney disease (CRD), which often leads to an increased anion gap due to accumulation of measured anions as kidney clearance decreases, result to metabolic acidosis which further compromise kidney and heart functions [23, 21]. While electrolyte imbalances and the anion gap are among the established indicators of systemic health disturbances, their relationship with prolonged occupational exposure to cement dust still remains under explored [24] Also despite the well demonstrated effect of cement dust inhalation of human health, there is a paucity of research on its effects on serum electrolyte levels and onion gap. This raises the intriguing question of how serum electrolyte and anion gap change over time with long term exposure to cement dust inhalation: hence the necessity for this research work.

Materials and Methods

The study was a cross sectional one conducted in Enugu Metropolis of Enugu state of Nigeria, using some prominent building construction sites. Blood specimen was collected from 60 construction site workers who had been exposed to cement dust for a minimum of 5 years. Another group of 30 individuals who had no history of cement dust exposure were used as control. Male workers in the construction industries/sites within the age range of 18-60 years who had been exposed to cement dust up to 5 years were included in the text study while those below 18 and above 60 years of age, smokers and those who had history of liver, kidney and respiratory disease were excluded. Males at the age range of 18 – 60 years who were not exposed to cement dust and without history of liver, kidney and respiratory diseases were used as control group. Personal protective equipment including N-95 respirator for protection from inhalation of cement dust during the study were used.

Laboratory Analysis

Serum electrolytes: Ion-Selective Electrode (ISE) method [25] was used for quantitative estimation of sodium, potassium, chloride and bicarbonate.

Principle: The principle of ISE method is based on the Nernst equation, which relates the potential difference across the membranes of the electrode to the concentration of the ion of interest. The membrane of an ISE is selective to a particular ion, and the potential difference generated across the membrane is proportional to the logarithm of the ion activity in the sample. The ISE is connected to a reference electrode and the potential difference between the two electrodes is measured using a voltmeter. The voltmeter measured is then converted into a concentration reading using the Nernst equation. ISEs offer several advantages, including high sensitivity, selectivity, wide dynamic range, and ability to measure activity directly, making them valuable tools for analysis of serum electrolytes

Procedures

Analytical procedures: A daily calibration using standard solution of the analyte in two points (low and high analyte values). The calibration curve is used to correlate the measured potential with the known concentration.

The ISE system is prepared by warming up the analysis ensuring clean and functional system with internal control which is usually run twice daily. The samples were respectively aspirated into the analyzer which its analyte selective electrodes detect the voltage potential due to the specific analyte ion. The reference electrode provides a stable potential. The signal in the system is processed and the analyzer converts the analyte(ion) potential and the respective analyte concentration to millimole per liter(mmol/L).

Anion gap: Calculation method of anion gap [26] was used.

Principle: The anion gap is typically calculated as the difference between the serum concentration of sodium and the sum of chloride and bicarbonate as shown in the following formular below [27].

Anion Gap = Na+ - (cl - + Hco3-), where [Na+], [cl^-] and [Hco_3^-] represent the serum concentration of sodium, chloride and bicarbonate respectively. The calculation is used to help evaluate the acid base disorder in Patients.

Ethical Considerations

This research conformed to the Helsinki declaration on bio medical research [28]. Written informed consent was obtained from all participants before their enrollment in the study. The institutional review Board (IRB) of ESUT College of Medicine approved the study protocol.

Statistical Analysis

Data obtained was analyzed using the statistical package for social science (SPSS) Inc, Chicago, IL, USA. For window software version 21. Continuous variable were represented as means and standards deviations while categorical variable were presented as numbers (percentages). Comparisons between means were carried out using the student t-test while comparison between percentages was carried out using chi-square test. The level of statistical significance was set at P value less than 0.05.

Results

Table 1: Changes in Serum Electrolytes and Anion Gap Levels with Long-Term Exposure to Cement Dust

Variable	Exposed Group (N=60)	Unexposed (Control)	T-Test	P (P-Value)
Sodium	140.2 ±1.83	141.2±1.52	0.009	<0.05
Potassium	4.24±0.03	4.04±0.17	0.000	<0.05
Chloride	100.8±1.66	101.9±1.9	0.006	<0.05
Bicarbonate	25.09±1.18	25.55±0.89	0.038	<0.05
Anion gap	17.53±2.8	16.78±2.3	0.019	<0.05

Table 1: Presented changes in serum electrolytes levels with long-term exposure to cement dust inhalation (test) group and the unexposed (control) group. The sodium level of the exposed group is lower than the unexposed group showing a significance difference (P<0.05), potassium levels were significantly higher in the exposed group compared to the in exposed group (P<0.05), chloride levels also showed a significant reduction in the exposed group compare to the unexposed group (P<0.05). Similarly bicarbonate levels in the exposed group were significantly lower than the unexposed group (P<0.05). The table also showed a significant increase in Anion Gap.

Discusion

Following a tremendous increase in demand for building and road constructions demand for cement, a binding agent used in constructions equally increased. As a result human constructions workers become inherently more exposed to cement dust of which contents of calcium oxide, iron oxide, chromium, silicon dioxide, aluminum oxide, sulfur et cetera, could have deleterious effect on human health at long term inhalation.

Using Ion-Selective Electrode method [25], serum electrolytes from sixty cement dust exposed and thirty unexposed workers were quantitatively analyzed and summary of results presented in table 1 above.

The serum sodium level of the cement dust exposed group was significantly lower than the unexposed group (P<0.05). This reduction in the sodium level signifies a disturbance in the electrolytes balance due to the long-term exposure to cement dust. This finding is supported by a past research work which observed that chronic exposure to dust in cement related industries is associated with disruptions in sodium balance, potentially linked to the high alkalinity of cement dust which can affect both respiratory and renal system [29]. Cement dust content of silica, calcium oxide and aluminum oxide can cause chronic respiratory inflammation which may activate inflammatory cytokines (eg, il-6, TN F-d) which stimulate hypothalamic pituitary adrenal (HPA) axis, leading to release of antidiuretic hormone (ADH) or vasopressin which promotes water retention by the kidney or reduction in serum sodium despite adequate sodium intake [30]. The reduction in serum sodium may have also been additionally contributed by the cement dust content of chromium, a heavy metal, at which long-term exposure can damage renal tubules that may lead to impaired reabsorption of sodium, thereby reducing serum sodium level and increasing sodium loss via-urine [31]. Potassium level was observed to be significantly higher in the test group than the control group. Higher potassium level in the test group suggests a possible response to kidney stress or other compensatory changes due to long-term exposure to cement dust. This finding is consistent with some previous studies; for instance the research work of El-shazly *et al*, 2021 [32], demonstrated an elevated serum potassium in workers exposed to cement dust. Cement dust which contains highly alkaline substances becomes caustic upon contact with moisture, can lead to systematic tissues damage (Rhabdomyolysis in severe case), on long-term exposure thereby causing intracellular potassium to leak into the extracellular fluid and blood stream to cause elevated serum potassium [33].

With reference to the table 1 above, chloride level was significantly reduced (P<0.05). The finding is in agreement with physiological conditions of body fluid compartment and electrolytes balance [34]. The finding is also supported by the research review work of Mount D B, 2014 [35] on renal physiology, sodium-chloride transport and chemical nephrology.

Serum bicarbonate level was also lower in the cement dust exposed group than the control group. Bicarbonate acts as buffering agent and a slight reduction might reflect compensatory changes due to body's need to neutralize alkaline dust. This result aligns with the finding by Nguyen *et al*, 2019 [36], who suggested that cement dust inhalation could shift acid-base homoeostasis over time due to its impact on respiratory and metabolic functions.

The study also found a significant increase in the anion gap among the exposed group compared to the control group. The anion gap reflects the balance of anions and cations in the blood and a higher gap suggests metabolic disturbances or an imbalance in acid base regulations. Our result is in consonance with Zhu *et al*, 2021 [37], who found that exposure to cement dust might affect acid-base balance as the body adjusts to the inhaled alkaline particles. Significant increase in anion gap level is indicative of metabolic acidosis in subjects exposed to cement dust over a long time [23].

Concltion

The result underscores the potential health risks associated with long-term exposure to cement dust inhalation, notably on serum electrolytes and anion gap. These finding align with prior research, supporting the notion that cement dust exposure places significant disturbance on serum electrolytes levels, acids base balance and anion gap.

Recommendations

The research findings highlight a clear need for protective and preventive measures in workplace with cement dust exposure, Providing workers with effective respiratory protective equipment, improving workplace ventilation, and implementing "dust suppression" practices could significantly mitigate the risks. Regular monitoring of serum electrolytes and anion gap is recommended for early detection and management of associated potential health issues. Additionally, educational programs focusing on the hazards of cement dust and proper use of safety equipment would support a culture of health awareness and precaution among cement workers.

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