Evaluation of lead, cadmium, copper and zinc levels and studying their toxic effect in sera of private electrical generator workers

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Abstract. According to the electricity crisis in Iraq since 1991, private electrical generators have installed randomly in nearly every neighbourhoods of all Iraqi cities. This represents a dangerous and uncontrollable environment that may lead to an environmental disaster. The aim of this work is to assess the serum levels of certain elements including lead (Pb), cadmium (Cd), Zinc (Zn) and Copper (Cu) and their health effect. This study included individuals working with electrical generators (n=60) and healthy (n=60) as control group, their ages ranged from 18 to 45 years. The obtained results indicate a significant increase (p <0.01) in the Pb, Cd, Cu levels and Cu/Zn ratio, in contrast to the significant decrease in the Zn level of the workers who exposed to the generator’s diesel exhaust fumes compared to the control group. A number of health issues such as allergies, shortness of breath, eye irritation, colds and some other respiratory problems were also recorded for exposed workers. From these results it can be concluded that direct exposure to the exhaust fumes of private generators could lead to heavy metals poisoning, especially Pb and Cd, which can lead to serious health consequences in particularly, the workers with long-term exposure. In addition, it can lead to an increased oxidative stress disorders that caused by disturbances in Cu and Zn levels.

1. The Introduction

The electricity shortage in Iraq has become a major problem since the 1991 Gulf War. For nearly three decades, the use of private electrical generators has spread widely in Iraq to reduce power outages. Generally, private generators are installed in neighborhoods and city centers where there is no street or neighborhood are empty of them, without being bound by environmental standards. It was found that the generators produce smoke including toxic substances resulted from the fuel combustion that contain lead, cadmium and other materials. This smoke is directly inhaled especially by generator’s operators [1], which can result in the deposition of heavy metals in the respiratory system leading to respiratory diseases such as asthma2, allergies, eye irritation, nose and shortness of breath [3,4]. The accumulation of toxic heavy metals over time in the body can lead to serious illness [5]. This damage can range from mild (i.e., irritation) to severe (i.e., carcinogenic, teratogenic and mutagenic), and varies among individuals and the duration of exposure. Some cases might exhibit clear symptoms, yet many cases show no symptoms even with elevated levels of heavy metals in the body [6]. In fact, heavy metal toxicity is increased the production of reactive oxygen species (ROS) that contribute to
oxidative damage, and the subsequent effects on health [7]. Long-term exposure to generator’s smoke might lead to an imbalance in the body, where essential minerals can be replaced by heavy metals, for instance zinc is replaced by cadmium and calcium is replaced by lead due to the similarity in the oxidation states [8]. Also, an imbalance of the antioxidants lead to the interruption or destruction of human and cell metabolism, because it also affects enzyme activity and functions of many hormones [9].

Environmentally, Pb exists in various forms including; organic (i.e., gasoline additives) which could cause lead poisoning and inorganic compound [10]. Organic Pb compounds can affect the central nervous system through skin absorption or inhalation, which consequently leads to permanent brain damage as well as reproductive system and heart issues, but the mechanism of this effect is still unclear [11].

Cadmium is an environmental toxicant and a powerful carcinogen harmful to reproductive health. Its greatest accumulation occurs in the kidneys and liver and has an endocrine effect, affecting the regulation and synthesis of hormones [12]. Cadmium oxide, cadmium chloride and cadmium sulfide which are released into the atmosphere during the development of various industrial processes, smoking and burning of waste and fuels [13]. Cadmium has a variety of toxic effects including nephrotoxicity, carcinogenicity, teratogenic effect, endocrine and reproductive toxicity [14-16].

Zinc plays a very important role in inflammatory processes and has an antioxidant role. The role of zinc supplementation has been shown to reduce markers of oxidative stress [17]. Zinc is also essential in growth and development. It is involved in building tissues and components of body fluids [18]. It is an essential component of a large number of enzyme metabolism pathways, it also acts as a catalyst in the synthesis of insulin and contributes to the protection of organs and cells [19-21]. Zinc deficiency leads to cognitive impairment, growth delay, anemia, impaired memory, impaired immunity, hair loss, impotence, and delayed wound healing, which affects the onset of many inflammatory diseases due to an increase in the production of pro-inflammatory cytokines [22-25].

Copper is an essential component of a variety of enzymes involved in metabolic reactions, and in oxido-reductase enzymes as an essential cofactor [26]. Copper binds to histamine during inflammatory processes [27]. It helps in the conversion of superoxide to oxygen and hydrogen peroxide in Superoxide Dismutase (SOD) [5]. It is an essential nutrient needed for the brain and nervous system, essential for the growth and building of bones, and its deficiency leads to osteoporosis, as well as nerve damage and tingling sensations in the feet and hands, in addition to irritability, confusion and even mild depression [18, 28-30]. Copper and zinc are involved in many biological processes, as they participate in the structure and functions of many enzymes, such as Cu/Zn superoxide dismutase with antioxidant and anti-inflammatory activity [31].

This study aims to estimate and evaluate copper, zinc, cadmium and lead released by the electrical generators to the environment and their health effects on workers who operate and control private generators installed in Baghdad-Iraq.

2. Materials and Methods

2.1. A Exposed workers and controls

This study was conducted in the Poison Centre at Ghazi Hariri Hospital for Specialized Surgery/Ministry of Health, and Chemistry department/College of Science/ Mustansiriyah University, Baghdad, Iraq between August and November 2020. This study included 120 people ranged from 18 to 45 years. The subjects included electrical generator’s workers (n = 60) with mean age of 30.98 years, selected from different areas in Baghdad, and normal control group (n = 60) with mean age of 29.66 years, randomly selected from the population with no work history in this field. Control and patients groups were sorted based on their age and sex. All subjects were informed of the objective of the research and their consent were obtained prior to initiating the study.

2.2. Sample collection, preparation and analytical methods
From each individual, five ml of blood was drawn into a gel tube through a vein puncture using disposable syringes. After collection, the blood samples allowed to clot for 15-20 min at room temperature, then centrifuged at 4000 rpm for 10 minutes. The resulting serum was stored at -20 °C prior to analysis.

Serum elements content Cu, Zn, Cd and Pb of all samples were estimated using flame atomic absorption spectrophotometer (FAAS, Model AA646, Shimadzu Corporation, Kyoto, Japan). Serum samples were diluted with 10-fold deionized distilled water (nanopure water (18.3Ω)). Determination of Cu, Zn, Cd and Pb was performed at wavelengths 324.7 nm, 213.9 nm, 228.8 nm and 287 nm, respectively. A standard calibration curve was built for each element using the following concentrations (0.05, 0.1, 0.2, 0.4, 0.8, 1.6, and 2 μg/ml). The accuracy of the measurements was confirmed using a certified reference material, NIST SRM 1640A Trace Elements in Natural Water (National Institute of Standards and Technology (NIST), USA).

2.3. Statistical Analyses:
Data was analyzed using SPSS statistical software, version 25. Independent-Samples Student t-test was performed between exposed worker and control groups, and the resulting values were expressed as mean and standard deviation (mean±SD). A level of p-value less than 0.05 was considered significant.

3. Results and discussion
The detailed statistical analyses of the data were presented as mean ± standard deviation and p-values in Table 1. Significant difference in serum levels was reported for all studied parameters between the exposed workers and controls. The serum levels of lead, cadmium, and copper in the patient group were found to be elevated when compared to the levels of the control group as presented in Table 1 and figures 1 and 2. In contrast, the serum zinc levels of exposed workers showed a clear decrease compared to the control group (see Table 1 and Figure 1).

The results showed that the mean ± SD of lead in the exposed group was 28.38 ± 3.1 μg/dL which was significantly higher than the control group (14.61 ± 2.2 μg/dL), Cd in the exposed group was 0.377 ± 0.06 μg/dL compared to the control group (0.149 ± 0.02 μg/dL), Cu in the exposed group was 155.86 ± 10.2 μg/dL in comparison to the control group (118.85 ± 11.6 μg/dL), whereas for Zn in the exposed group was 71.08 ± 5.2 μg/dL which was significantly lower compared to the control group 98.21 ± 10.8 μg/dL.

The relationship between all elements included in the present work was assessed using Pearson’s correlation analysis which are presented in Table 2. A positive correlation between Pb versus Cd levels, Pb versus Cu levels, Cd versus Cu levels were observed for the exposed workers. On the other hand, a negative correlation was observed between the levels of Zn and other elements (i.e., Pb, Cd and Cu) levels.

| Metal | Study group | Student t-test | p value |
|-------|-------------|----------------|---------|
|       | Exposed Mean ± SD | Control Mean ± SD |          |         |
| Pb (μg/dl) | 28.38 ± 3.1   | 14.61 ± 2.2    | 29.004  | 0.001   |
| Cd (μg/dl)  | 0.377 ± 0.06  | 0.149 ± 0.02   | 27.876  | 0.001   |
| Cu (μg/dl)  | 155.86 ± 10.2 | 118.85 ± 11.6  | 18.557  | 0.001   |
| Zn (μg/dl)  | 71.08 ± 5.2   | 98.21 ± 10.8   | 17.555  | 0.001   |
Figure 1. Shows the differences in mean values of Pb, Cu and Zn (µg/dl) levels in serum of exposed workers and control groups.

Figure 2. Shows the differences in mean values of serum Cd (µg/dl) level between exposed workers and control groups.

Table 2: Correlations between examined metals in serum of exposed workers (p-value)

| Element | Lead  | Cadmium | Copper  | Zinc       |
|---------|-------|---------|---------|------------|
| Lead    | 1     | 0.94 ** | 0.786 **| -0.779 **  |
| Cadmium | 0.94 **| 1       | 0.807 **| -0.803 **  |
| Copper  | 0.786 **| 0.807 **| 1       | -0.872 **  |
| Zinc    | -0.779 **| -0.803 **| -0.872 **| 1          |

**Indicates significant at 0.01 level
Many gases and complex compounds are emitted with fumes of electrical generators that cause air pollution and the harmful consequences of public health, especially for those who work with these generators [32]. The human body may absorb the chemical elements present as very dangerous free ions, as these elements could form stable covalent complexes and interact with the biological macromolecules such as proteins, enzymes and hormones based on their chemical properties (e.g., oxidation state) [33]. However, there is only a slight prospect that the ions will combine with biomolecules to induce cytotoxicity, sensitivity and other biological effects.

The present results are in agreement with a previous study that showed an increase in the concentration of lead in the serum of workers in large private generators [11]. Clinical diagnosis of lead poisoning may be difficult because individuals with lead poisoning can be asymptomatic and thus the diagnosis of environmental lead exposure may be late in most cases. It has been reported that lead can adversely affect the antioxidant system [34], by forming reactive oxygen species (ROS) and thus causing oxidative stress. It has been found that oxidative stress is mainly involved in many health problems and causing many human diseases. In fact, lead can be stored in various parts of the body, especially in the bones, liver, kidneys and brain, in addition to increasing lead levels in the blood [35].

The high levels of cadmium observed in this study may increase ROS production and thus cause oxidative stress. Cadmium is known to be one of the most toxic elements among the heavy metals in the human body. It has been found that cadmium poisoning can cause dangerous conditions in humans, including high blood pressure, kidney damage and red blood cell destruction [36]. In fact, cadmium levels need to be monitored in environmental samples especially for those who work with electrical generators.

Based on the obtained results in this study, it is clearly shown that there is a significant increase in copper levels for workers with electrical generators. Indeed, copper plays an essential role in the antioxidant defense system of many physiological enzymes including cytochrome c peroxidase and Cu-Zn SOD [37]. In fact, although copper is an essential component of the human body, high levels of copper can lead to an increased formation of toxic ROS, which in turn may lead to an increased risk of developing oxidative stress disorders.

Zinc has been shown to be effective in more than 300 enzymatic reactions. In addition, it plays an important role in axon and synaptic transmission, and is essential for DNA metabolism, brain development, and phosphorylation as well as a critical role in the antioxidant defense system [38]. The results of this study showed a decrease in the zinc level in exposed workers compared to controls, indicating that this decrease may be a public health risk factor. It was found that zinc has antioxidant-like properties and thus has the ability to stabilize macromolecules against excess production of ROS [5]. It can be concluded that lower levels of zinc in the serum of exposed workers may be due to its participation in the antioxidant defense system because these workers may be under the “higher oxidative stress” category.

In fact, the serum Cu/Zn ratio has been used in previous studies to assess the antioxidant defense system linked with some diseases [39, 40]. In the current study, it was found that the ratio of Cu/Zn was significantly increased in the serum of workers with electrical generators (2.19) compared to controls (1.21). In conclusion, the result indicates that the Cu/Zn ratio can be of great value for general health assessment of generator workers as well as a good indicator for assessing the antioxidant defense system.

4. Conclusion
Minerals are associated with many biological processes important to organisms, as they require to present in stable form and level, and any imbalance (e.g., increase or decrease) leads to an imbalance in the ionic balance and this causes an imbalance in biological processes. Therefore, it is necessary to search for the causes of pollution that lead to deviate the balance and set strict standards to maintain the environmental balance to ensure people comfort and safety.

In this study, and based on laboratory investigation, the mean values of lead, cadmium and copper were significantly higher, while the mean value of zinc was significantly lower in the blood of the
exposed workers compared to the control individuals. These results increased the risk of oxidative stress disorders. The personal evaluation, for the exposed workers, revealed the presence of symptoms of respiratory allergies, eye irritation, shortness of breath and cold, especially when starting generators without using protective devices such as masks. This indicates the presence of environmental pollution as a result of the fumes generated from fuel combustion, and this could cause serious conditions and problems in the future. Therefore, it can be suggested that special standards should be set for the distribution of generators within residential areas and for the use of environmentally friendly fuel in addition to the use of preventive means such as masks.

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