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Study of the Effects of Carbon Monoxide (CO) and Sulfur Dioxide (SO_2) on Some Physiological Blood Parameters among Electric Generator Workers in Al-Najaf Al-Ashraf City

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Abstract:

Background: Electric generators workers are unceasingly exposed to a lot of hazardous and toxic fumes that has the potential to cause many health complications. **Objective:** The aim of this study was to evaluate effect of gases rising from electrical power generators on physiological blood parameters, liver and kidney functions in of workers in electrical generators in Al - Najaf Al-Ashraf city. **Methodology:** The study noted that all the quarters selected in southern sector during morning period have decibel levels above the recommended limits set by Iraqi-standards and WHO. **Results:** the results recorded that there was elevation in carbon monoxide (CO) concentration emitted by electrical generators in south sectors compared with permissible limits of gaseous air pollutants emission from electrical power generators in Iraq. The results recorded that there was elevation in carbon monoxide (CO) and sulphur dioxide (SO_2) concentrations emitted by electrical generators in north and south sectors compared with permissible limits of gaseous air pollutants emission from electrical power generators in Iraq. the results showed that there was a significant elevation ($P \leq 0.01$) in total leukocyte count of electrical generators

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workers comparison with control group. **Conclusions**: the result for current study indicated that there was a significant increment (P≤0.01) in hemoglobin and packed cell volume of electric generators workers compared with control group.

Keyword: CO, SO_2, Pollutants, Physiological and Biochemical Blood parameters, Electric Generators Workers

1. Introduction:

Electric generators have been widely installed throughout Iraq, resulting in some rather ingenious constructions. Many generators emit gases and insulation compounds, which pollute the air and negatively impact the health of their workers [1]. The main pollutants from domestic power generators include carbon monoxide (CO), carbon dioxide (CO2), sulfur oxides (SOx), carbon dioxide (CB), nitric oxides (NOx), and particulate matter (MP) [2]. Air pollution is one of the world's biggest mathematical problems. Large quantities of carbon dioxide, especially carbon monoxide from spacecraft, are released into the air daily [3]. [4] Studies have shown that the short-term effects of carbon dioxide emissions can cause heartburn, cardiovascular problems, eye strain, drowsiness, headaches, death, loss of consciousness, cancer, and chronic obstructive pulmonary disease (COPD) [5]. Elevated cadmium and copper levels have been reported in private generator operators compared to a control group. This study aims to achieve the following objectives:

1. To assess the gaseous pollutants levels that emitted from city of Najaf electrical power generators.

2. To determine gases effect of emitted from electrical power generators on blood physiological markers and indicators.

2. Literature Review:

2.1. Environmental Pollution:

The world today is experiencing widespread and unprecedented pollution. Among the most prominent types of environmental pollution are air pollution, soil pollution, nuclear

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pollution and water pollution [6], as well as noise pollution [7]. Environmental pollution is defined as "an undesirable change in our surrounding environment, such as small wastes released into the environment by human activities, or living organisms and large particles harmful to humans [8] "

Humans are causing serious damage to the atmosphere, water, land, various environmental elements, and the ecosystem itself. The main types of environmental pollution include land pollution, air pollution, marine pollution, water pollution, and others. In addition to these, there are other types such as noise pollution, nuclear pollution, thermal pollution, visual pollution, and others [9].

2.2. Air pollution due to electrical power generators:

Numerous studies have shown that the gases and compounds emitted from diesel generators cause air pollution and have a negative impact on the public health of the workers who operate these generators. Estimates indicate that these emissions include nitrogen oxides (NOx), carbon monoxide (CO), carbon dioxide (CO2), fine particulate matter (PM), volatile organic compounds (VOCs) and sulfur oxides (SOx), [2,10,11].

2.3. Effects of CO And SO_2 Pollutants on different organs and systems

2.3.1. Carbon monoxide:

Carbon monoxide (CO) is a odorless, colorless, and tasteless gas that is difficult for humans to detect. It is called the "silent poison of the 21st century" and the "silent killer" because it gives no warning to its victims of danger. Poisoning with small amounts of carbon monoxide causes oxygen deficiency and neurological damage in humans [12].

2.3.1.1. Carbon monoxide toxic kinetics:

In the respiratory system, after inhalation, inhaled carbon monoxide is absorbed in the gas exchange zone. In the liver, methylene chloride is converted to carbon monoxide after absorption. The half-life of carbon monoxide may be prolonged due to continued metabolism and absorption following exposure to methylene chloride. Most carbon monoxide is reversibly bound to hemoglobin in red blood cells, while relatively small amounts bind to cytochromes or remain in solution.

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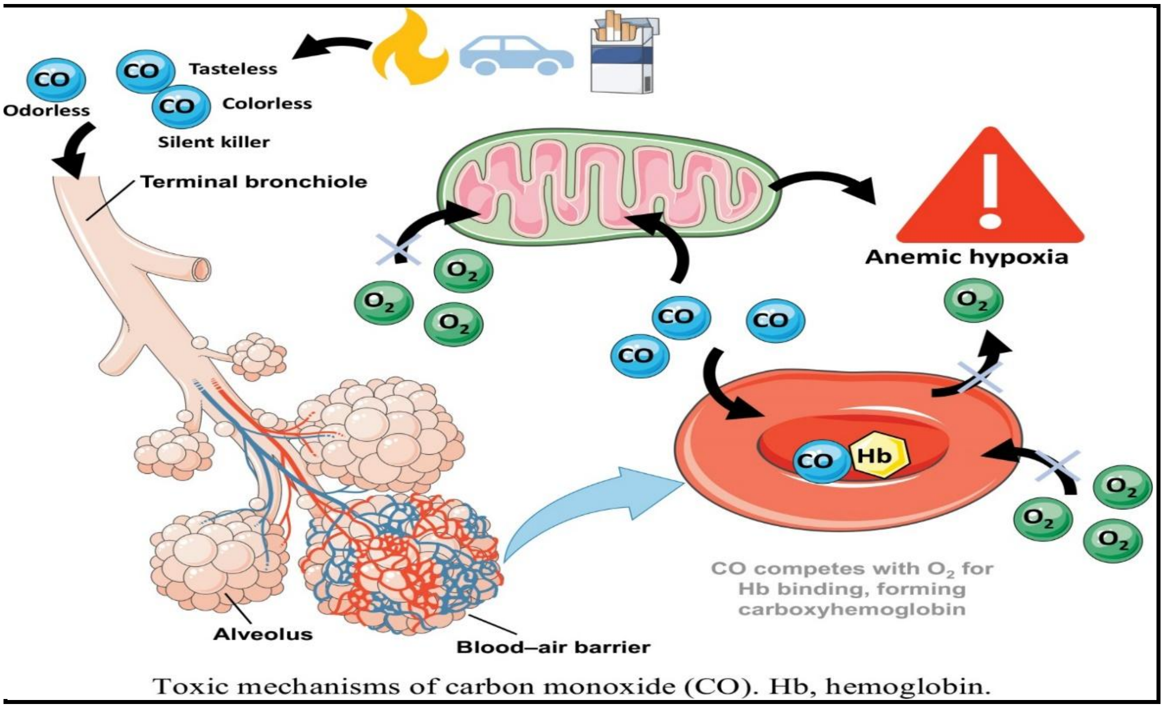

Figure 2.1. Toxic mechanisms of CO and Hb. (13).

2.3.1.2. Carbon monoxide poisoning:

Carbon monoxide poisoning usually occurs as a result of inhaling large amounts of it. Symptoms are often described as flu-like and typically include dizziness, headache, weakness, mental confusion chest pain, and vomiting, Severe exposures can lead to heart rhythm disturbances, seizures, loss of consciousness, or death. Severe skin redness is rare. Long-term complications may include chronic fatigue, mobility issues and memory problems, [14].

This can occur as a result of using vehicles, heating appliances, or cooking equipment that run on carbon dioxide. Carbon monoxide causes harmful effects primarily by combining with hemoglobin to form carboxyhemoglobin (HbCO), which prevents the blood from expels carbon dioxide and transporting oxygen as carbaminohemoglobin. In addition, many other heme proteins are affected, such as mitochondrial cytochrome oxidase and myoglobin, cytochrome P450, along with other non-metallic and metallic cellular targets [15].

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The highest recorded non-fatal carboxyhemoglobin level was 73%. Symptoms of carbon monoxide poisoning include: Weakness, Shortness of breath, Confusion, Loss of consciousness, Dizziness, Mild headache, Blurred vision and Nausea or vomiting

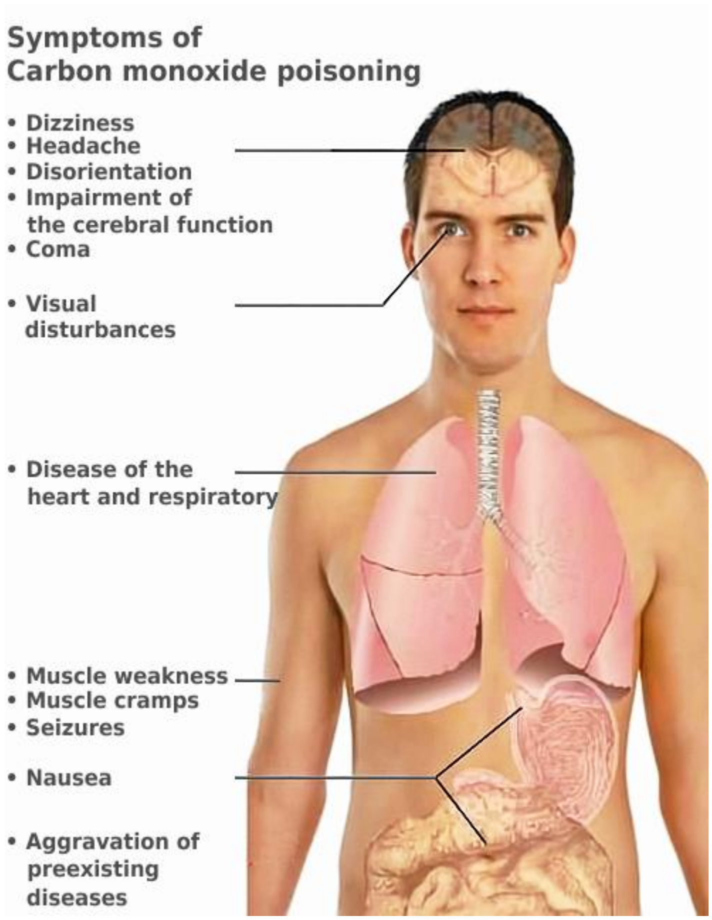

Figure 2.2. Symptoms of CO poisoning (16)

2.3.2. Sulfur dioxide (SO_2):

Sulfur dioxide is a chemical compound with the formula SO. It is a toxic gas responsible for the smell of burning matches. It is emitted naturally by volcanic activity and is also produced as a byproduct of copper mining and the burning of sulfur-containing fossil fuels. Sulfur dioxide has a pungent odor similar to that of nitric acid [17].

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2.3.2.1. Sulfur dioxide poisoning:

Sulfur dioxide poisoning typically occurs through inhalation or exposure to air, causing a burning wheezing, watery eyes, pain in the mucous membranes, and coughing. It can also exacerbate underlying lung conditions such as chronic obstructive pulmonary disease (COPD) and asthma. Occupational exposure to sulfur dioxide is a common cause of poisoning in fields such as coal refining, metallurgy, and chemical processing.

3. Materials and Methods:

3.1. Materials:

3.1.1. Study Area:

The city of Najaf is one of the most important cities in Iraq from a religious and historical perspective. It is located southwest of Baghdad, on the western plateau of Iraq, the capital of Iraq, at a distance of 160 kilometers. It is characterized by a high population density, with an estimated population of 1,500,522, and an area of 28,824 square kilometers. The city is divided into five sectors: first, the Old City sector (Al-Mashriq, Al-Buraq, Al-Umrah, and Al-Hawash); second, the Al-Jadadat sector (Al-Jadadah 1,2,3,4); third, the southern sector, which includes the right side of the Kufa-Najaf road extending from Najaf to Kufa; fourth, the northern sector, which includes the area on the left side of the Kufa-Najaf road; and fifth, the Al-Radawiyah sector.

3.1.2. Gaseous air pollutants measurement:

Gaseous pollutant emissions from power generators in Najaf city center were measured. The study included various power generator locations, distributed across the northern and southern sectors of the city. Measurements were taken at distances ranging from two meters (2 m) to five meters (5 m). A high-precision GM8805 portable carbon monoxide meter (0–1000 ppm) and a BX 170 portable sulfur dioxide detector were used for the measurements of carbon monoxide (CO) and sulfur dioxide (SO2). The average generator operating time was 12 hours per day.

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3.1.3. Study population:

The study included thirty workers operating diesel-powered electricity generators and thirty healthy individuals as a control group for comparison. The medical history of the participants was collected. The characteristics of the workers in large private electricity generating stations included mean length of service (6.23 ± 0.68 years), age (30.68 ± 1.29 years), height (75.83 ± 1.70 m), weight (22.32 ± 0.42 kg), and body mass index (1.60 ± 0.12 kg/m²) (Table 3.1).

Table: (3.1) Demographic and anthropometric characteristics of the study participants

Characteristic	Unit	Electric Generator Workers (Mean ± SD)	Healthy Controls (Mean ± SD)
Age	Years	30.68 ± 1.29	30.11 ± 8.05
Body Mass Index (BMI)	kg/m²	1.60 ± 0.12	1.61 ± 0.03
Height	m	75.83 ± 1.70	74.21 ± 10.63
Weight	kg	22.32 ± 0.42	22.07 ± 3.38

Mean ±SD: mean ± standard deviation

3.2. Methods:

3.2.1. Questionnaire surveys:

The questionnaire was administered to 30 workers selected from different regions. Data were collected through face-to-face workplace interviews using a pre-designed questionnaire at large private power plants in Najaf, Iraq. All participants completed the questionnaires during the study. The first questionnaire included items related to personal information, such as demographic characteristics, work history of the power plant workers, and a medical history table (3.4). The second questionnaire included a section on noise-related symptoms (3.5).

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Table (3.2) Study questionnaire form for electrical generators workers.

Name of quarters: ………………., Date: ……. /……./ …….. . ,			
First part: Demographic characteristics:			
Name of workers		**Date of birth**	
Height (Cm)		**Weight (Kg)**	
Education		**Marital status**	
Address			
Smoking:	**Yes** ☐ **No** ☐		
Second part: Work history in the electrical generator's workers:			
How long have been working at these electrical generators?			
How many hours in days?			
How many days in week?			
Did you use protective equipment at work	**Yes** ☐ **No** ☐		
Third part: Medical history:			
Have you ever had any of the following health problems?			
Asthma	**Yes** ☐	**No** ☐	
Chronic bronchitis	**Yes** ☐	**No** ☐	
Anemia	**Yes** ☐	**No** ☐	
Inflammation	**Yes** ☐	**No** ☐	

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Table (3.3) Symptoms caused by noise questionnaire form.

Name of workers: ………………., Date: ……. /……./ …….. .		
Symptoms List:		
Do you have **headache**?	Yes ☐	No ☐
Do you feel dizziness?	Yes ☐	No ☐
Do you feel annoyance?	Yes ☐	No ☐
Do you feel impaired **hearing**?	Yes ☐	No ☐
Do you have **tinnitus**?	Yes ☐	No ☐
Do you have **ear pains**?	Yes ☐	No ☐
Do you have **sleeplessness**?	Yes ☐	No ☐
Do you feel deafness?	Yes ☐	No ☐
Do you feel tiredness?	Yes ☐	No ☐
Do you feel deafness?	Yes ☐	No ☐
Since when have you been having these symptoms at work?	Month	Year
Are you using any medicines?	Yes ☐	No ☐
Which medicines?		

3.2.2. Blood sampling:

The samples were collected as follows:

a. From each of the electrical power generator sets, venous blood was collected (8 milliliters).
b. Two milliliters of this blood were placed in EDTA-containing tubes for measuring hematological parameters in the control group

while the remaining six milliliters were placed in serum tubes for assessing biochemical parameters, antioxidant indices liver, and kidney function tests, to separate the serum of these tubes were centrifuged at 3000 rpm for five minutes, which was then collected in

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aliquoted into Eppendorf tubes, new tubes, and stored in a freezer (-20°C) until measurement.

3.2.3. BMI (Body Mass Index):

The weights and heights of the tow studied groups were measured using a precision-calibrated scale. Height was recorded in centimeters and weight in kilograms (kg). Body mass index (BMI) was calculated according to the following equation [18]. BMI (Kg/m^2) = Weight (Kg)/ (Height (m))^2

3.2.4. Hematological parameters tests:

Hematological parameters of blood samples were determined using DYMIND DF50 5-Part Auto Hematology Analyzer. This instrument is a fully automated hematology analyzer diagnosed complete blood count (CBC). It provided a quick screening for hematological testing.

3.2.5. Gaseous air pollutants measurement:

Sulfur dioxide and Carbon monoxide emissions from power generators in Najaf city center were measured using a BX 170 portable sulfur dioxide detector (World Marine Supply Co., Ltd., China) and BENETECH GM8805 portable digital carbon monoxide meter (Shenzhen Liweihui Technology Co., Ltd., China). The study included various power generator sites in the northern and southern sectors of Najaf. Measurements were taken at distances ranging from 2 meters to 5 meters

The portable carbon monoxide meter features a digital display, a key feature that provides an advanced level of protection. The device is easy to install, and the alarm system has been carefully designed and tested to detect carbon monoxide concentrations in a residential environment (Figure 3.1).

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Figure: (3.1) GM8805 Handheld Carbon Monoxide Meter

Figure: (3.2) BX 170 portable gas detector sulphur dioxide (SO_2).

3.2.6. Statistical Analysis:

The data were statistically analyzed using (Statistical Package for the Social Sciences) SPSS version 24. The analysis of variance (ANOVA) and independent samples t-test were used. All values were expressed as mean ± standard error of the mean. A p-value less than 0.05 and 0.01 was considered statistically significant [19].

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Results:

4.1 Gaseous air pollutants concentrations (ppm) measurements:

4.1.1. Evaluation of Carbon Monoxide (CO) and Sulfur Dioxide (SO_2) Emissions from Electrical Power Generators

The results showed elevated levels of carbon monoxide (CO) emitted from power generators in both the northern and southern sectors compared to the permissible limits for gaseous air pollutant emissions from power generators in Iraq (Table 4.6). Similarly, the results showed elevated levels of sulfur dioxide (SO2) emitted from power generators in both sectors compared to the permissible limits for gaseous air pollutant emissions from power generators in Iraq (Table 4.1). The current study revealed no significant difference in CO concentration emitted from the southern sector compared to the northern sector (Table 4.6). The results in Table 4.1 indicated that the sulfur dioxide (SO2) concentration emitted from power generators in the southern sector was higher than in the northern sector (Table 4.6). The study also demonstrated that the concentrations of both carbon monoxide (CO) and sulfur dioxide (SO2) exceeded the nationally permissible maximum limits.

Table (4.1) Concentrations of gaseous pollutants emitted from electrical generators in the northern and southern sectors compared with Iraqi permissible limits

Pollutant	Unit	South Sector Generators (Mean ± SEM)	North Sector Generators (Mean ± SEM)	Iraqi Permissible Limit
Carbon Monoxide (CO)	ppm	1.35 ± 0.15	1.43 ± 0.19	0.26
Sulfur Dioxide (SO_2)	ppm	0.99 ± 0.11	0.83 ± 0.11	0.14 (24 h)

SEM = Standard Error of the Mean. Maximum permissible concentration of carbon monoxide (CO): 35 ppm for a 1-hour exposure period and 9 ppm for an 8-hour exposure period. Maximum permissible concentration of sulfur dioxide (SO_2): 0.15 ppm for a 1-hour exposure period and 0.04 ppm for a 24-hour exposure period.

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4.2. Hematological parameters:

4.2.1. Total and differential counts of leukocytes:

4.2.1.1. **Hematological Assessment of Total and Differential Leukocyte Counts Among Electrical Generator Workers and Control Subjects**

The results showed that there was as comparison with control group, a significant elevation (P≤0.01) in electrical generators workers total leukocyte count (Table 4.2). Regarding, differential leukocytes count, the results recorded that no significant elevation in percentage of electrical generators workers neutrophils in comparison with control subjects (Table 4.2). Moreover, the statistical analysis exhibited that no significant increment in percentage of electrical generators workers lymphocytes count in comparison with control group as represented in (Table 4.2).

Also, the result found that there was no significant difference in monocytes and eosinophils for electrical generators workers in comparison with control subjects (Table 4.2). Furthermore, the result for current study recorded that significant (P≤0.01) decrement in percentage of basophils for electric generators workers compared with control group (Table 4.2).

Table (4.2) Hematological parameters in electrical generator workers and control subjects

Hematological Parameter	Control (n = 30)	Generator Workers (n = 30)	P-value	Interpretation
Total Leukocyte Count (×10³ cells/mm³)	5.63 ± 0.04	7.14 ± 0.20	≤0.01	Highly Significant
Neutrophils (%)	51.02 ± 2.30	56.71 ± 1.72	0.064	Not Significant
Lymphocytes (%)	24.95 ± 3.80	30.41 ± 1.80	0.210	Not Significant
Monocytes (%)	5.31 ± 0.30	5.18 ± 0.31	0.860	Not Significant
Eosinophils (%)	3.84 ± 0.45	3.47 ± 0.40	0.640	Not Significant
Basophils (%)	0.928 ± 0.05	0.612 ± 0.04	≤0.01	Highly Significant

Notes: HS = Highly significant. NS= non-significant. SEM = Standard Error of the Mean

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4.2.2. Total red blood corpuscles and RBCs indices:

4.2.2.1. Comparison of Total Red Blood Cell Count and Erythrocyte Indices between Electrical Generator Workers and a Control Group

The statistical analysis showed in compared with control group; there was no significant differences in electrical generators workers total red blood corpuscles (Table 4.3). However, the result for current study indicated that there was a significant increment ($P \leq 0.01$) in packed cell volume and hemoglobin of electric generators workers compared with control group (Table 4.3).

The result of the study also found no significant change in mean corpuscle volume and mean corpuscle hemoglobin of electrical generators workers in comparison with control group (Table 4.3). Also, it can be clearly seen that significant ($P \leq 0.01$) decrement in mean corpuscle hemoglobin concentration in electrical generators workers compared with the control group (Table 4.3).

Table (4.3) Comparison of erythrocyte indices between electrical generator workers and control subjects

Parameter	Unit	Control Subjects (n = 30) Mean ± SEM	Generator Workers (n = 30) Mean ± SEM	P-value	Significance
Total RBC Count	$\times 10^6$ cells/mm³	5.03 ± 0.02	5.15 ± 0.04	0.130	NS
Hemoglobin (Hb)	g/dL	13.18 ± 0.06	14.29 ± 0.13	≤ 0.01	HS
Packed Cell Volume (PCV)	%	40.92 ± 0.25	44.08 ± 0.35	≤ 0.01	HS
Mean Corpuscular Volume (MCV)	fL	84.50 ± 0.70	85.48 ± 0.66	0.190	NS
Mean Corpuscular Hemoglobin (MCH)	pg	27.40 ± 0.21	27.76 ± 0.27	0.120	NS
Mean Corpuscular Hemoglobin Concentration (MCHC)	g/dL	33.30 ± 0.06	32.50 ± 0.10	≤ 0.01	HS

Notes: HS = Highly significant. NS= No-significant . SEM = Standard Error of the Mean.

5. Discussion:

5.1. Gaseous air pollutants Concentration:

5.1.1. Distribution of Carbon Monoxide (CO) and Sulfur Dioxide (SO_2) Emissions from Electric Power Generators in Different Sectors of Al-Najaf City During Morning and Evening Periods

The results showed increased concentrations of carbon monoxide (CO) and sulfur dioxide (SO2) emissions from power generators in the northern and southern sectors, compared to the permissible limits for gaseous air pollutant emissions from power generators in Iraq (Table 4.6). These results are consistent with those of a previous study [20], in which researchers measured gaseous air pollutant emissions from diesel generators in downtown Kut during summer and winter. That study found that emissions from diesel generators ranged from 25 to 68 tons of carbon monoxide (CO), from 189 to 515 tons of nitrogen oxides (NOx), from 10,428 to 28,335 tons of carbon dioxide (CO2), from 8 to 21 tons of volatile organic compounds (VOCs), from 66 to 180 tons of sulfur oxides (SOx), and from 23 to 64 tons of particulate matter (PM). [21] reported that the significant increase in electricity production in Iraq would lead to serious environmental challenges due to the substantial rise in the production of various pollutants. Gas-fired power plants constitute approximately 50% of the production systems, while heavy oil-fired steam power plants account for 28%, and diesel power plants for 15%. The main pollutants emitted from power plants include carbon dioxide, carbon monoxide, nitrogen oxides, sulfur oxides, and particulate matter. The findings showed that the annual amount of carbon dioxide emitted from all Iraqi governorates, except Kurdistan, more than doubled between 2005 - 2014, from 7.33 million tons to 14.54 million tons.

[22] This study measured environmental pollutants emitted by electric power generators in the city of Kova. The study covered the period from 2009 to 2017. The total amount of pollutants increased by approximately 108% during this period. This rapid increase in the total amount of pollutants is attributed to the increase in electricity production. Most generators use diesel fuel, with consumption reaching 6,695 tons in 2009 and then rising to 13,933 tons in 2017, representing a 108% increase. The amount of

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various pollutants was estimated according to the standard fuel emission index for diesel internal combustion engines. The pollution levels can be categorized into the following pollutants: nitrogen oxides carbon dioxide, carbon monoxide, particulate matter and sulfur dioxide. The actual standard fuel emission index is based on determining the amount of the sulfur dioxide pollutant. Carbon dioxide was the main pollutant due to its high emission index. The annual amount of gaseous pollutants emitted, such as nitrogen oxides, carbon monoxide and sulfur oxides, increased from 21, 62.8 tons 161 kilograms respectively in 2009 to 43 tons, 130.7 tons and 335 kilograms respectively in 2017.

The study revealed that the amount of gaseous pollutants emitted annually from commercial power generators exceeds 5,000 tons, and that the concentration of these pollutants is significantly higher in older vehicles compared to newer ones. These pollutants are generally produced by photochemical reactions in the atmosphere, leading to the formation of secondary pollutants. The quantity and quality of fuel used in electricity generation in generators affect environmental pollution, with diesel being one of the most polluting fuels. Many gas station owners resort to mixing different types of fuel, such as diesel with kerosene, which increases environmental pollution and damages power generation engines. The findings revealed high levels of noise and air pollution, as well as environmental and public health problems associated with the use of diesel generators in Nigeria.**5.2. Hematological parameters:**

4.2.1. Assessment of Total and Differential Leukocyte Counts

4.2.1.1. Comparison of Total and Differential Leukocyte Counts Between Electrical Generator Workers and Healthy Control Subjects

The results indicated a significant increase ($P \geq 0.01$) in the total white blood cell count among generator workers compared to the control group (Table 4.2). This significant increase ($P \geq 0.01$) in the total white blood cell count may be attributed to exposure to air pollutants and to potential correlations between atmospheric carbon monoxide concentrations and inflammatory biomarkers. Carbon monoxide and/or other air pollutants have direct effects on the immune system, indirectly through alterations in blood biomarkers. [23] Gaseous pollutants have been shown to increase the release of white blood cells and their precursors from the bone marrow via a non-strain-specific mediator

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produced by alveolar macrophages during their phagocytosis of fine particles. Nevertheless, the results of this study have provided valuable insights into the potential relative contribution of various air pollution components to the bone marrow response.

Study of [24] showed a significant increase in white blood cell count among workers exposed to lead compared to those not exposed. Furthermore, generator operators experience occupational stress due to excessive noise in the workplace. Numerous studies have reported that exposure to various physical and psychological stressors can increase the secretion of stress hormones such as corticosterone, cortisol, noradrenaline and adrenaline [25, 26]. The current study demonstrated that exposure to workplace pollutants leads to a significant increase in total white blood cell count among generator operators, resulting in respiratory tract inflammation. [27] Similar results were reported in an experimental study on mice, revealing a statistically significant increase in the number of white blood cells, monocytes, and neutrophils. The researchers suggested that the increased white blood cell count might be related to the various effects of lead on humoral immunity, specifically serum immunoglobulin levels. This is likely due to the occupational exposure of workers to large quantities of gaseous air pollutants through inhalation and the resulting inflammatory effects.

Regarding the differential white blood cell count, statistical analysis showed no significant increase in neutrophil and lymphocyte percentages among generator workers compared to the control group (Table 4.7). This is attributed to the effects of inhaling gaseous air pollutants, which vary in toxicity level, duration of exposure, and degree of inflammation caused by these pollutants. [28] has found that the human hematopoietic system is highly sensitive to the effects of environmental pollution due to the rapid cell formation process and its associated metabolic demands. Furthermore, the observed increase in lymphocyte count among generator workers may be a defense mechanism of the body.

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5.2.2. Total red blood corpuscles and RBCs indices:

5.2.2.1. Assessment of Red Blood Cell Count and Erythrocyte Indices Among Electrical Generator Workers and Healthy Controls

The current study did not show any statistically significant differences in total red blood cell count among generator workers compared to the control group (Table 4.3). However, the results of the current study indicated a significant increase ($P \geq 0.01$) in packed cell volume and hemoglobin levels among generator workers compared to the control group (Table 4.3). This is most likely attributed to the workers' exposure to various air pollutants emitted by generators, particularly the high levels of carbon monoxide and sulfur dioxide in the workplace. The effects of carbon monoxide include compensatory responses to tissue hypoxia resulting from its binding to hemoglobin (e.g., hemoglobin level, increased blood volume, hematocrit, volume red and blood cell count).

Carbon monoxide (CO) is produced by its combination with hemoglobin (Hb). The direct binding of carbon monoxide to the hemoglobin molecule reduces the blood's oxygen-carrying capacity, and the presence of carboxyhemoglobin (COHb) alters the dissociation properties of the remaining oxyhemoglobin (HbO_2), making less oxygen available to the tissues. Carbon monoxide causes toxicity through its binding to hemoglobin, reducing its oxygen-carrying capacity, and through its binding to myoglobin cerebral ischemia, and leading to potentially impairing cardiac output [29].

Human health is closely linked to the environment [30]. In general, air pollution is considered a major contributing factor to many diseases, such as cardiovascular and respiratory diseases and lung cancer. Carbon monoxide has a toxic effect on health through oxygen deprivation and has an affinity for hemoglobin (Hb) that is 210–240 times greater than that of oxygen (O_2). Approximately 80–90% of absorbed carbon monoxide binds to hemoglobin to form carboxyhemoglobin (COHb), which reduces the blood's ability to carry oxygen and leads to tissue hypoxia [31]. Furthermore, the results showed no statistically significant change in mean corpuscular volume (MCV) and mean corpuscular hemoglobin concentration (MCHC) among the generator workers compared to the control group (Table 4.3). A significant decrease ($P \geq 0.01$) in MCHC was also observed among the generator workers compared to the control group (Table 4.8). [32] studied the

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hematological parameters of workers at the Sanandaj Power Plant (EPSW) with a control group. The results indicated that the EPSW group exhibited higher levels of RDW (red blood cell distribution width), lymphoma, SGPT, and lower levels of MCH (mean corpuscular hemoglobin concentration), MCHC (mean concentration of corpuscular hemoglobin), neutrophils and monocytes, compared to the control group. Several hematological abnormalities were observed among the Sanandaj Power Plant workers, highlighting the need for safety procedures in this type of work environment. Studies [33, 34, 35] have indicated that the pathological mechanism that explains the possible relationship between air pollution and glucose levels is related to an inflammatory response that may disrupt the metabolism of fats and glucose.

These results are likely due to prolonged exposure to noise pollution, leading to increased red and white blood cell counts, as well as elevated hemoglobin and hematocrit levels. [36] noted that a slight increase in blood lead levels was associated with an increased red blood cell count, as well as increased hemoglobin and hematocrit levels, in an experimental study conducted on mice. [36] also reported similar findings in an experimental study on mice, where elevated levels of red blood cell size differential (RDW) may reflect impaired red blood cell formation. Various cancers pose a significant risk when these workers are exposed to generator gases for extended periods (approximately more than a year).

Conclusions:

The following points can be concluded from this study:

1. The results of this study showed elevated concentrations of carbon monoxide (CO) and sulfur dioxide (SO_2) emitted from power generators in the northern and southern sectors compared to the permissible limits in Iraq. The study also indicated that the concentration of carbon monoxide (CO) and sulfur dioxide (SO_2) was higher than the Iraqi national standard.
2. The hematological analysis showed a significant elevated in values of total leukocyte, percentage of neutrophils count, packed cell volume and hemoglobin in blood of electrical generators workers comparison with control group.

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3. The study, based on survey analysis, showed that headaches (50%) and discomfort (39%) were the most common types of symptoms caused by noise among generator operators.

Recommendations:

1- Increase environmental awareness about the use of the generators among population by relying on the media especially TV and radio, social media and education. Electrical generators workers should be educated about different hazardous effects of pollutants on their health. Health education on the hazards of generator uses and related environmental issues should be promoted in our society.

2- Workers operating generators should be advised to use personal protective equipment, such as earplugs safety and goggles, masks, while working with generators, in addition to undergoing regular medical checkups. These measures will help identify workers at risk in a timely manner.

3- The easiest way to reduce generator noise is to increase the distance between residential areas and the location of the diesel generator. When the generator is moved further away, the power is distributed over a greater distance, thus reducing the noise level.

4- Generator noise should be minimized. This can be achieved using sound barriers, soundproof walls, and fences. Solid surfaces reduce noise transmission by reflecting sound waves. Soundproof fences are also available that help keep decibel levels to a minimum.

References

1. Mehde, A. A., Yusof, F., Mezal, S. A., Farhan, L. O., & Mehdi, W. A. (2015). Study the effect of increased levels of lead on sera alpha amylase activity, and some biochemical parameters from a large private electrical generators workers. *Advances in Environmental Biology*, *9*(8), 163–167.
2. Gorman, D., Drewry, A., Huang, Y. L., & Sames, C. (2003). The clinical toxicology of carbon monoxide. *Toxicology*, *187*(1), 25-38.

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3. Poursafa, P., & Kelishadi, R. (2010). Air pollution, platelet activation and atherosclerosis. *Inflammation & Allergy-Drug Targets (Formerly Current Drug Targets-Inflammation & Allergy)(Discontinued)*, *9*(5), 387-392.
4. Al-Fartusie, F. S., & Mohssan, S. N. (2017). Essential trace elements and their vital roles in human body. *Indian J Adv Chem Sci*, *5*(3), 127-136.
5. Al_Saadi, M. R., Al-Fartusie, F. S., & Thani, M. Z. (2021, March). Evaluation of lead, cadmium, copper and zinc levels and studying their toxic effect in sera of private electrical generator workers. In *Journal of Physics: Conference Series* (Vol. 1853, No. 1, p. 012044). IOP Publishing.
6. Kara, E., Genc, M., & Kaya, M. (2015). Environmental pollution: Air, water, soil and nuclear. *International Journal of Research and Development*, *7*(1), 1-5.
7. Romeu, J., Genescà, M., Pàmies, T., & Jiménez, S. (2016). Acoustic environmental zoning as strategy of management and control of the urban noise pollution. Proceedings of the 22nd International Congress on Acoustics.
8. Cunningham, W. P., & Saigo, B. W. (2001). Environmental science: A global concern (6th ed.). McGraw-Hill.Vas
9. Vesilind, P. A., Peirce, J. J., & Weiner, R. F. (2013). Environmental pollution and control (3rd rev. ed.). Butterworth-Heinemann. ISBN: 9781483140728
10. Hardy, K. R., & Thom, S. R. (1994). Pathophysiology and treatment of carbon monoxide poisoning. Journal of Toxicology: Clinical Toxicology, 32(6), 613–636. https://doi.org/10.3109/15563659409017973
11. Townsend, C. L., & Maynard, R. L. (2002). Effects on health of prolonged exposure to low concentrations of carbon monoxide. *Occupational and Environmental Medicine*, *59*(10), 708-711.
12. Weaver, N. B. (2009). Carbon monoxide poisoning. New England Journal of Medicine, 360(12), 1217–1225. https://doi.org/10.1056/NEJMcp0808891.
13. Blumenthal, I. (2001). Carbon monoxide poisoning. Journal of the royal society of medicine, 94(6), 270-272.
14. Prockop, L. D., & Chichkova, R. I. (2007). Carbon monoxide intoxication: an updated review. Journal of the neurological sciences, 262(1-2), 122-130.

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15. Rose, J. J., Wang, L., Xu, Q., McTiernan, C. F., Shiva, S., Tejero, J., & Gladwin, M. T. (2017). Carbon monoxide poisoning: pathogenesis, management, and future directions of therapy. *American journal of respiratory and critical care medicine*, *195*(5), 596-606.
16. Kliegman, R. M., Behrman, R. E., Jenson, H. B., & Stanton, B. M. (2007). Nelson textbook of pediatrics e-book. Elsevier Health Sciences.
17. Chen, T. M., Kuschner, W. G., Gokhale, J., & Shofer, S. (2007). Outdoor air pollution: nitrogen dioxide, sulfur dioxide, and carbon monoxide health effects. *The American journal of the medical sciences*, *333*(4), 249-256.
18. Eknoyan, G. (2008). Adolphe quetelet (1796-1874) the average man and indices of obesity. Nephrology, dialysis, transplantation : official publication of the European Dialysis and Transplant Association - European Renal Association, 23(1), 47–51.
19. Daniel, W. W. (2010). Biostatistics: A foundation for analysis in the health sciences (9th ed.). John Wiley & Sons.
20. Khalaf,K.A.; Jubeir,A.J. & Kazem,S.K.(2009).estimating study for calculating electrical diesel generators emissions in the center of kut city.. *Journal Of Wassit For Science & Medicine*, *2*(2).
21. Jassim, H. M., Fakhri, H. I., & Hayfaa, A. J. (2016). Environmental impact of electrical power generators in Iraq. *International Journal of Engineering Technology, Management and Applied Sciences*, *4*(3), 122-134.
22. Abbas, H. H., Ibraheem, F. H., & Maaroof, A. A. (2019). Pollution Problems in Koya City due to Private Electrical Generators. Aro-the scientific Jurnal of Koya University, 7(2), 38-46.
23. Tan, W. C., Qiu, D., Liam, B. L., Ng, T. P., Lee, S. H., van Eeden, S. F., D'Yachkova, Y., & Hogg, J. C. (2000). The human bone marrow response to acute air pollution caused by forest fires. American Journal of Respiratory and Critical Care Medicine, 161(4), 1213–1217. https://doi.org/10.1164/ajrccm.161.4.9906161
24. Lorenzo, Ó., Urbé, S., & Clague, M. J. (2006). Systematic analysis of myotubularins: heteromeric interactions, subcellular localisation and endosomerelated functions. *Journal of cell science*, *119*(14), 2953-2959.

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25. Wankhar, D.; Sheela Devi, R. and Ashok, I.(2014). Emblica officinalis outcome on noise stress induced behavioural changes in Wistar albino rats. Biomed Prev Nutr. ,4(2):219-24

26. Monsefi, M., Bahoddini, A., Nazemi, S., & Dehghani, G. A. (2006). Effects of noise exposure on the volume of adrenal gland and serum levels of cortisol in rat. Iranian Journal of Medical Sciences, 31(1), 5–8.

27. MuGahi, M. N., Heidar, Z., SaGheb, H. M. and Barbarestani, M. (2003): Effects of Chronic lead acetate intoxication on blood indices of male adult rat. DARU 11(4): 147-151.

28. Jude, L. C., Sasikala, K., Kumar, R. A., Sudha, S., & Raichel, J. (2002). Haematological and cytogenic studies in workers occupationally exposed to cement dust. International Journal of Human Genetics, 2(2), 95–99.

29. Haymond, S., Cariappa, R., Eby, C. S., & Scott, M. G. (2005). Laboratory assessment of carbon monoxide poisoning. Clinical Chemistry, 51(2), 481–483. https://doi.org/10.1373/clinchem.2004.041699

30. Folinsbee, L. J. (1993). Human health effects of air pollution. Environmental Health Perspectives, 100, 45–56. https://doi.org/10.1289/ehp.9310045

31. Giles, L. V., Koehle, M. S., Sissons, K., Sandhu, M. S., & Taunton, J. E. (2014).

32. . Nadimi, H., Jalili, A., Mohammadi, K., & Nadimi, V. (2017). Studying the amount of blood parameters and liver enzymes in the workers of Sanandaj Power Plant. Open Journal of Clinical Diagnostics, 7(2), 52–61. https://doi.org/10.4236/ojcd.2017.72005

33. Eze, N. C., Okonkwo, I. N., & Onuoha, S. C. (2015). Assessment of some haematological parameters in workers occupationally exposed to petroleum products in Umuahia, Abia State, Nigeria. International Journal of Research in Medical Sciences, 3(11), 3232–3236.

34. Xu, X., et al. (2011). Association of polycyclic aromatic hydrocarbons (PAHs) exposure with hematological parameters in coke oven workers. Journal of Occupational and Environmental Medicine, 53(12), 1422–1426.

35. Zheng, Z., Xu, X., Zhang, X., Wang, A., Zhang, C., Hüttemann, M., Grossman, L. I., Chen, L. C., Rajagopalan, S., Sun, Q., & Zhang, K. (2013). Exposure to ambient

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particulate matter induces a NASH-like phenotype and impairs hepatic glucose metabolism in an animal model. Journal of Hepatology, 58(1), 148–154. https://doi.org/10.1016/j.jhep.2012.08.009

36. Iavicoli, I., Carelli, G., Stanek III, E. J., Castellino, N., & Calabrese, E. J. (2003). Effects of low doses of dietary lead on red blood cell production in male and female mice. *Toxicology letters*, *137*(3), 193-199.

37. Golalipour, M. J., Roshandel, D., Roshandel, G., Ghafari, S., Kalavi, M., & Kalavi, K. (2007). Effect of lead intoxication and D-penicillamine treatment on hematological indices in rats. *International Journal of Morphology*, *25*(4), 717-722..

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